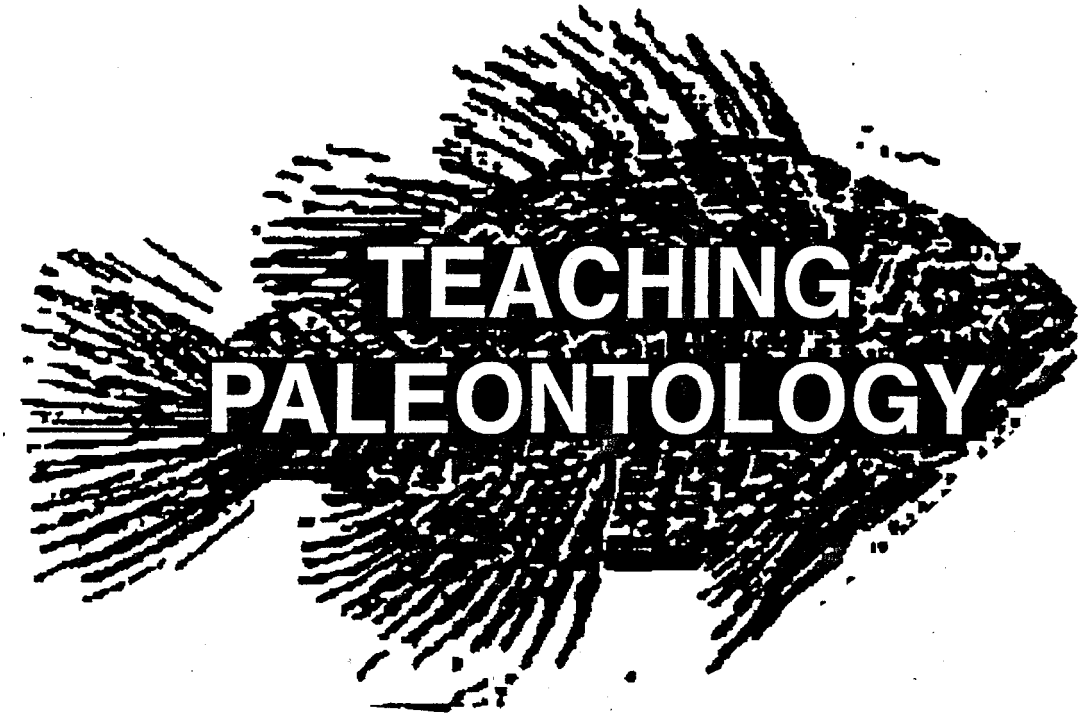

IN THE NATIONAL PARKS AND MONUMENTS AND PUBLIC LANDS

A Curriculum Guide for Teachers of the Second and Third Grade Levels

Teaching Paleontology in the National Parks And Monuments and Public Lands

A Curriculum Guide for Teachers of the Second and Third Grade Levels

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Procduced by the National Park Service, Fossil Bute National Monument,
Kemmerer, Wyoming, 1995

Forward

This curriculum guide for paleontology was developed by Fossil Butte National Monument as part of its growing environmental education program. It is designed to be used by teachers as an aid in presenting principles of fossils and past life to students in the second and third grades.

Paleontology involves the integration of a number of different areas of expertise. We hope these exercises will help teachers to encourage the various talents their students have to offer. While only a minority of students may feel a calling to become scientists, those who do not will, with luck, be stimulated by the cultural or artistic aspects of paleontology, and perhaps better identify with scientists in general. The primary message of these units should be that science is fun.

The concepts of ancient life and geologic time are the focus of paleontology. These are difficult concepts for anyone to understand, especially children. The study of paleontology including a field experience has the potential to bring these concepts to life by showing, for example, that fossils can be found hear home, and that by learning about them we can learn much about our own environment and how it has changed.

The national parks and monuments and public lands can play an important part in bringing paleontology into the lives of children. Fossil resources of National Park Service (NPS) units are protected but available to all the public, through all types of exhibits. Furthermore, NPS staffs are knowledgeable of the resources under their protection and are willing to tell school groups about them. Many national park units with fossil resources have visitor centers with museums and interpretive trails that are well suited to educational experiences. The Bureau of Land Management (BLM) administers about 270 million acres of public lands in 11 western states. Many areas on these lands could be used as outdoor paleontology laboratories and classrooms. Although a permit is required to collect vertebrate fossils, teachers and students may collect common invertebrate and plant fossils for classroom use on the public lands.

A study of paleontology in the classroom will benefit immensely from a visit to a national park or monument, or the public lands. We encourage teachers to take advantage of these resources, which offer a personal classroom for informal learning. Appendix A lists national park units that have important fossil resources. Included in this list are some of the facilities of the parks that might be of special interest to school groups. Appendix B lists areas on the public lands where there are interpretive exhibits on paleontology, and BLM State Offices where information on additional lands can be obtained.

Organization and philosophy

This guide is organized into four units: Unit 1, fossilization and human influences, for the second grade; and Unit 2, adaptation, Unit 3, community, and Unit 4, human influences, each for the third grade. These units are best presented in the sequence given, since each assumes a certain background covered by previous units. However, this background material could be presented separately without too much difficulty. The exercises in each unit can be done in the order and manner presented or separately, as part of a fossil curriculum designed by the teacher

A vocabulary list follows a short summary introduction to each unit. Understanding of most of these terms is necessary for complete comprehension of the lesson material. In some cases the teacher may find it necessary to discuss in detail the concepts behind these terms. The text following the vocabulary lists contains discussions of those concepts. Teachers may want to consult other reference materials. A list of references for teachers and students to help in understanding and expanding on the material present is given at the end of each unit.

The pre- and post-questions are intended for classroom discussion. If a test or written exercise is desired, the teacher could prepare one using these questions as a guide. All questions are repeated in Appendix E as classroom handout sheets.

The exercises are intended to be hands-on. Children are naturally motivated by objects and benefit from tangible examples, especially if they are allowed to manipulate them. Paleontologists also are typically object-oriented people who follow a hands-on approach to their work. In this way the exercises are realistic. However, rather than actual specimens, this kit includes casts of real fossils for several reasons. Hands-on use in the classroom places specimens in danger of damage or loss. Fossils are non-renewable natural resources, most of them irreplaceable. Fossil plants and invertebrates are typically more abundant, but vertebrate fossils, especially, are rare and valuable. Because of the quality of molding and casting processes today, casts not only have the advantage of durability and replaceability_ but also of very accurate replication of fossil material. In fact, many modern museum displays of fossil vertebrates are constructed entirely of casts.

Beyond science

We hope that this guide will help teachers go beyond teaching paleontology as "science" and introduce paleontological themes into other areas of study. For example, connections to the visual arts could be explored by having the class paint or sculpt scenes from the past imagined through their studies of fossils (see Activity 4 and Activity 9, Variation 1). A classroom activity such as Activity 15 (a . food web) could be done as a performance. The class could learn a poem or song about fossils. Learning about geologic time could also be used as an introduction to large numbers in a mathematics unit.

The planning chart in Appendix E stresses the different subjects that the theme of paleontology can enhance. The first chart is filled in with suggested ways this could be done; the second is left blank so the teacher can make copies and experiment with various customized plans.

Field trips

Classroom lessons would be complemented by a field trip to a site of paleontological interest. Pre-site activities are best done before the field trip, post-site activities after it. We encourage teachers to take advantage of the staffs of nearby NPS units or local BLM offices to help them in planning field trips. These staffs will also be helpful for advice if, for example, controversial situations arise in teaching paleontology in the classroom.

A teacher does not need to be an expert in paleontology or geology to lead a good field trip for children. He or she need only have a basic knowledge of the age of the rocks and types of environments and fossils that are present in the area to be visited. This information can be gotten from the staffs of museums, parks, or geology departments. Many parks and monuments have special programs available for school groups. These programs may include ranger-led hikes, speciallydesigned activities with fossil themes, Junior Ranger programs, and fossil demonstrations. In many cases, a ranger will visit the classroom.

We recommend that you call the park you intend to visit well in advance of a planned field trip. Early scheduling will give you a better chance of getting the desired date. Spring and fall are popular times for visits to parks and monuments. When scheduling a visit, be sure to let the rangers know what you have been studying. There may be special activities in which your students can participate.

While this guide was developed for use in conjunction with a trip to a national park or monument, teachers without easy access to an NPS unit will often be able to find other sites where fossils may be found, such as mines, quarries, or gravel pits, or on the public lands. Consult with your local BLM office or your state geological survey for the location of geologically and paleontologically significant areas nearby. Geologists and paleontologists at nearby natural history museums can also provide information and may even help you plan a field trip. The appendices list addresses and phone numbers for geological surveys and many museums.

The advantages of seeing rocks and fossils in the field cannot be overstressed. Specimens and photographs will help students recognize certain fossils and visualize ancient environments, but actually seeing, touching, and possibly even collecting, a fossil in place communicates a far stronger message. A field trip allows the student to visit the actual site where the fossil organism lived and died. It allows him or her to see the actual sediments, now turned to rock, that entombed it. And the person who finds a fossil is often the first human ever to see this object Students will soon find that they can make original and noteworthy discoveries in paleontology.

Ideally, lessons taught on field trips should complement the emphasis of the current teaching unit, but should not be restricted by it if other interesting topics present themselves. For a field trip to be most effective, considerable time should be spent in the classroom preparing the students for what they will see and do in the field. This should include some geography, placing the trip destination in a regional and national context. Rudimentary geologic history should also be covered. This might include a simple stratigraphic column like the one in Appendix E. Students could color in the different rock units and illustrate their diagrams with fossils found in each unit. Discussion of geologic history should include, as a minimum, talking about the types of animals and plants that were living at the time the rocks of the field site were being deposited. Appendix D (geologic time scale) provides some basic geologic information. If you are planning a visit to a national

park or monument, park staff or publications available from the park may be able to provide additional background material.

Besides helping students learn about the importance of fossils, a field trip gives teachers the opportunity to make some other important points about the students' influence on science and society. By properly recording information about any fossils they end, students will assure that others will have access to this same information in the future. It is also important to report finds to experts, and to learn as much as possible about fossils in order to recognize a find that is rare or exceptionally important.

Proper field etiquette should be discussed in the classroom. On private land, stress that trespassing is not only bad manners but also illegal. Tell the students that you have talked with the landowner and he/she has given permission for the class to be there. In national parks and monuments, digging or collecting fossils is . not allowed without a scientific permit. On other federal land, collectors need permits for certain kinds of fossils.

Many national parks and monuments act as scientific laboratories where paleontologists collect and study fossils. The information gathered is sometimes presented to park visitors in educational programs developed especially for
them. Fossils on these lands belong to all people and are being protected and preserved for all generations.

• Planning a field trip A valuable .activity for the class could be to participate in the planning of a field trip by putting together a list of gear to bring along. Important items include clothing appropriate for the site and weather, a camera, notebook and pencils, water, and a lunch. Roc hammers, chisels, and collecting bags may be useful for a trip to a privately-owned site or lands administered by the BLM, but are forbidden in national parks. Be sure you get permission ahead of time from all landowners to enter or collect on private land. Land ownership can be researched using maps available at local BLM offices or other land management agencies. Maps are essential for determining the location of finds, and can help students learn how to get around in the field.

• Safety . The importance of safety in the field should be discussed prior to and during any excursion. If you are visiting a roadcut, please be extremely cautious, as traffic can make roadside outcrops very dangerous places to visit. Be extremely careful, both for yourself and others below you, when climbing around on loose rock. Watch out
for poisonous snakes that may be found in rocky areas. Be sure to carry plenty of water, wear a hat, and have other protection from the sun.

• Paleontology on a budget We realize that many schools are not able to take their students on field trips because of budget constraints. Many national parks and monuments, as well as some museums, have slide or video programs that they will loan to schools. These cannot take the place of an actual field trip, but may be the next best thing for those unable to travel.

A learning log

The ability to write clearly is among the most important skills that scientists, including paleontologists, need. Learning about the natural world is fun, but of limited use if you cannot communicate your results to the rest of the world. Children in the second and third grades are beginning to learn how to express themselves in writing. Learning about paleontology provides many opportunities for practicing written communication. Have the students start a personal "learning log" at the beginning of their paleontology study. Each day, set aside some time for them to write about their experiences for that day. They could also include drawings and other visual aids. When their studies are finished, their learning log, along with other materials accumulated, will document a set of pleasant experiences in paleontology.

Contents

Kit contents checklist

1. One plaster cast: Leaf, *Ptychocarpus* sp., Pennsylvanian, Illinois
2. One plaster cast: Brachiopod, wide-hinged spirifer, Pennsylvanian, Utah
3. Two plaster casts: Gastropod (snail), high-spiced shell, Tertiary
   Gastropods, *Goniobasis* sp., Eocene, Wyoming
4. One plaster cast: Crinoid, columnals (stem segments) of "sea lily," Paleozoic
5. One plaster cast: Shark tooth, *Otodus* sp., Miocene, Morocco
6. Two plaster casts: Fish, Green River Formation, Eocene, western Wyoming
7. One plaster cast: Dinosaur skin, found with bones of duckbill dinosaur, Cretaceous, Alberta, Canada
8. One plaster cast: Trilobite, *Phacops rana,* Devonian, Ohio
9. One plaster cast: (blue sticker) Lower jaw of fossil carnivore, *Thinocyon velox,* Eocene, western Wyoming
10. One plaster cast: Crinoid, Unidentified crinoid, Mississippian, Kansas
11. One plaster cast: Lower jaw of fossil omnivore (black sticker)
12. One plaster cast: (green sticker) Lower jaw of fossil herbivore, tapir, *Isectolbphus* sp., Eocene, Wyoming
13. One plaster cast: Lower jaw of coyote, modern carnivore/omnivore (yellow sticker)
14. One plaster cast: Lower jaw of rabbit, modern herbivore (orange sticker)
15. Plaster cast: plastic fish for fossilization activity, Unit 1
16. One slab: rock from Green River Formation, western Wyoming
17. Plastic cast: Fish and rock from Green River formation for preparation activity
18. One bag each: Plaster of Paris, modeling clay for teacher's use
19. One metal plate: Fossil rubbing
20. 25 magnifying lenses
21. One Poster: Geologic Time
22. One Map: National Parks and Monuments
23. Eight brochures: Fossil Parks in the National Park System
24. Three Brochures: A Guide to Fossil Parks, Fossil Collecting Issues, Fossil Collecting on Public Lands
25. Slide carousel: Introduction to fossils, Unit 1 (60 slides)
26. Slide carousel: Environments and adaptations, Unit 2 (34 slides)
27. Three discs: computer simulation, Unit 3
28. One video: Fossil Lake

UNIT ONE: FOSSILIZATION

Introduction

How does a living thing become a fossil? The mysterious processes by which evidence of past life is preserved are explored in this unit. By thinking about and participating in some simulated sedimentary processes, children will be able to remove much of the mystery behind fossils and fossilization. More than 60 parks and monuments of the National Park System contain significant fossil deposits. A strong understanding of fossilization processes will prepare students for a field visit to a fossil park or other fossil area on public lands.

This unit introduces the concept that fossils are remains or traces of ancient living things by giving students the opportunity to create their own "fossils." By studying some of the different ways that organisms can leave a fossil record (actual remains, impressions, footprints, natural casts and molds), students will be encouraged to think of other ways this can happen. They may also begin to think about how rare an event fossilization is. The concept of human influences is introduced by having the students play the roles of finders, collectors, and interpreters of fossils.

Objectives

After completing this unit students will be able to:

1) evaluate the importance of fossils to our knowledge of life;

2) identify conditions necessary for fossilization;

3) construct a possible scenario for formation of a fossil; and

4) devise a code of behavior based on ethical behavior for student paleontologists.

Materials included in the kit

slide carousel: introduction to fossils
plastic fish
plaster of Paris modeling clay

Optional materials

sheets of paper (newspaper is best; construction paper might not work)
X-acto or linoleum knife large,
shallow tray or plastic sheet shells,
leaves, or other potential "fossils" collected by the class
fine sand
mud of two different colors
small trays or pie plates
plastic spoons and knives or popsicle sticks
heavy-duty aluminum foil

VOCABULARY

Coprolite	(ko-pro-lite) Fossil dung.
Fossil	Any evidence of past life.
Fossilization	The processes that occur when evidence of past life is preserved. Not the same as mineralization or conversion to rock.
Natural resource	A naturally-occurring material that is useful to society.\
Paleontologist	(pay-lee-on-toPo-jist) A person whose job is the study of fossils and ancient life.
Scavenger	An animal that eats animals that are already dead.
Sediment	Naturally-occurring material transported and deposited by water or wind, such as mud, sand, peat.
Sedimentary rock	A rock made of tightly packed and cemented sediment.
Trace fossil	Evidence of an activity of a living thing. Examples: footprint, coprolite.

Overview

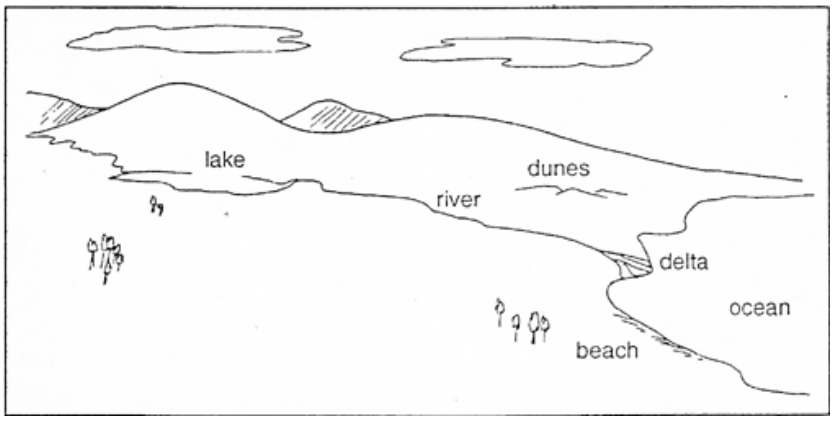
Definition of a fossil

A fossil can be defined as any naturally-occurring evidence of past life. Fossils need not be mineralized (turned to rock) or even enclosed in rock. Many relatively young (10,000 years old or more) Ice Age sedimentary deposits are uncemented sand and gravel, but rich with true fossils. Ice Age mammoths that have been found preserved in permafrost are fossils, although their flesh is still mostly undecayed. Ten thousand years is a lower limit often used for the age of organic remains that are considered fossils.

There are three basic types of rocks: sedimentary, metamorphic, and igneous. A field guide such as the Audubon Society Field Guide to Rocks and Minerals or an introductory geology textbook will discuss origins and help you identify rocks. With few exceptions, fossils occur in sediments or sedimentary rocks. Occasionally living things are preserved in lava flows or volcanic tuff deposits (igneous rocks), but these are relatively rare. Some metamorphic rocks (rocks changed by heat and pressure) contain fossils, but usually metamorphism destroys fossil details.

Sedimentation and fossilization

The fossilization process is intimately connected with sedimentary processes. Thus, environments where sediments are being deposited (depositional settings) are places where plants and animals have the potential to be fossilized. Examples of depositional environments include a lake bottom, a river sandbar, a beach, ocean floor, or dune field (see figure at right). Sediments originate from a variety of different sources. Some sediments result from the breakdown, through weathering, of pre-existing rocks; these are called clastic sediments. Common clastic sediments are sand, gravel, silt, clay, and mud. The sedimentary rocks they turn into are sandstone, conglomerate, siltstone, claystone, and mudstone, respectively.



(Some places where seidments could be deposited – depositional settings)

Organic sediments originate as tissues of plants or animals. Leaf litter on a forest floor is an example of organic sediment. Much sand and mud in marine environments results from the breakdown of shells or skeletons of animals (oysters and corals, for example) and plants (marine algae). This sediment is rich in calcium carbonate and forms the rock limestone. The organic sediment peat, usually deposited in a swampy environment, becomes, with heat and pressure, the sedimentary rock coal.

Still other kinds of sediment are formed when certain chemicals in a body of water reach too high a concentration to remain in solution, and precipitate out. An example is the evaporation of seawater to form salt. Some limestones also form this way.

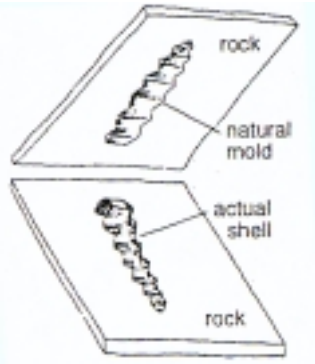
Regardless of the type of sediment or sedimentary environment in which an organism dies, fossilization is by no means guaranteed. There are a number of requirements that must be met before preservation of organic remains is assured. The difficulty of meeting all of these requirements is the reason that fossilization is a rare and chance occurrence. First, organisms that possess hard parts of some kind, such as bones, teeth or shells, stand a far better chance of fossilization than those that do not. Soft-bodied worms, for example, are extremely rare as fossils although they are common in marine and terrestrial settings. Absence of organisms with hard parts is the main reason that fossils from Precambrian time (see geologic time chart, Appendix D, page 77) are so rare.

The second requirement for fossilization is rapid burial in a protective medium. Upon death, the remains of most organisms are quickly acted on by scavengers and by microorganisms that promote decay. Physical action in the natural environment (e.g., currents, waves, wind, and rain) is also destructive. If the remains are to make it into the fossil record they must be buried quickly in an oxygen-free environment before these processes have a chance to destroy them. The type of sediment also affects the quality of fossil preservation; fine-grained sediments are more likely to favor the preservation of small details.

Examples of different kinds of fossilization

- Fish sinks to oxygen-free bottom of lake, buried in soft mud.
- Herd of animals drowns in flood, buried in river sand.
- Shell debris accumulates slowly on ocean floor
- Animals grazing on plains buried by sudden eruption of volcanic ash

Conditions after burial are also important in aiding or hindering preservation of organic remains. This stage in the process, the third requirement for fossilization, is called diagenesis. Diagenesis refers to everything that happens to a sediment after it is deposited. The effects of pressure, heat, and circulating fluids that in time turn a sediment into a sedimentary rock also act on the organic contents of the sediment, altering their composition and appearance. Sometimes a potential fossil maybe dissolved in the process of diagenesis. Other times it may become mineralized. Think of how hard water acts in a teapot or in water pipes over time; deposition of minerals in those places is similar to the mineralization process that cements sediments into rock. Mineralization (or petrification), in which a fossil effectively "turns to stone," may help preserve a fossil, but is not a requirement for fossilization. Many organic remains can be preserved essentially unaltered for millions of years and still be true fossils.



A fossil snail and its natural mold in the rock.

Not all fossils are actual remains of living things. Sometimes only an impression of the animal or plant is left behind after its death, such as a natural mold of a shell.

A good introduction to fossils is presented in the slide program "Introduction to Fossils" included in the kit. A useful exercise in discussing fossilization is the handout "The story of how a rabbit became a fossil," in Appendix E, pages 78-79.

Trace fossils

A trace fossil is evidence of some activity or behavior of an animal or plant while the organism was still alive. Some examples of trace fossils are footprints and trackways, burrows, coprolites, and root casts. Ancient ripple marks, mud cracks, or raindrops preserved in rock are called "sedimentary structures," but because they do not represent activities of living things, they are not trace fossils. Because actual remains of the organism that made a trace fossil are usually not preserved, the trace maker is often unknown. Trace fossils are nevertheless strong and valuable evidence that certain kinds of activities occurred in a given environment. They are useful in learning about the types of animals and their interactions in ancient environments.

A trace fossil: bird tracks in lake sediments.

Fossils as nonrenewable natural resources

Fossils of all kinds are the only direct evidence we have of past life. As such they are irreplaceable natural resources for science. It is important for students to understand that fossils should be used wisely, and that they can participate in their conservation. Private collecting of fossils is basically a good thing; amateur paleontologists can collect valuable information. But amateurs should always follow standards of professional ethics, including discussing their finds with experts in a position to recognise exceptional or valuable specimens. Good field records are necessary so that all finds can be exactly relocated. In addition, it is important for children to learn to respect public and private lands by not trespassing and by obtaining permission to dig or collect specimens.

Protection of fossil resources is aided by public facilities such as the National Park System and on lands administered by other federal agencies. In the national parks and monuments, fossils are protected from destruction and made available for educational and scientific use by the public.

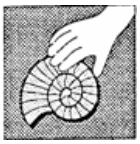
Pre-questions

1. What is a fossil? Refer to the definition in the vocabulary list

2. How does an animal or plant become a fossil? Use this question at the beginning to see how much the students know about fossils. The overview discussion describes three things that are usually necessary for an organism to become a fossil: hard parts, quick burial, and favorable conditions after burial (diagenesis).

3. Your footprints on the beach are evidence that you were there. Do you think you could call your footprints trace fossils? Why or why not? If they were still there after 20,000 years, could you call them fossils then? Footprints are examples of trace fossils. Most paleontologists would agree that remains or traces of any kind should be more than about 10,000 years old before they can be called true fossils.

ACTIVITY 1 One way a living thing could become a fossil



Message Fossils are remains or indirect evidence of past life. Plants and animals become fossils only under certain conditions.

Version 1-wet paper as sediment

I. Materials Sheets of white and colored paper of uniform size (newspaper works best); plastic fish skeleton; shallow tray, cake pan, or plastic sheet; water, sharp knife (like a linoleum knife); other simulated fossils.

II. Procedure

1. **Lay down paper "sediment."** do this exercise on the floor on a sheet of plastic or in a large, shallow tray. Wet the sheets of paper one by one and place several on top of each other on the plastic sheet or tray. Tell the students that the sheets of wet paper represent layers of sediment (mud, sand, etc.) being deposited over a period of many years in a lake. The students can participate by wetting the sheets and lining them up one atop the other. It is not necessary for the sheets to be wrinkle-free or perfectly lined up.

2. **Add the fish.** After several sheets (say, 10 to 20) have been placed, ask a student to place the plastic fish on the center of the "sedimentary pile." Emphasize that the fish recently died and has sunk to the bottom of the lake where these sediments are accumulating. The students may have other objects such as leaves, shells, or bones, that they can place between the "sediment' layers as they accumulate. This will make the exercise more interesting and will allow the direct participation of a larger number of children.

3. What happens next? After the fish is in place, discuss possible fates of this skeleton. Remember, the fish is not yet assured of becoming a fossil. Have the students think of some things that could happen to this skeleton that would prevent it from becoming a fossil. Possibilities: It could be eaten by a *scavenger*. It could decay. It could be washed away by currents. If and when the class decides that in this case the skeleton will not be destroyed and will have the opportunity to fossilize, you may proceed with more wetpaper sediment.

4. **Let the "sediment" turn into "rock."** When the pile of paper and potential "fossils" is an inch or so thick, stop the "sedimentation" and allow the pile to dry. This may take several days, depending on the conditions. Explain to the students that in reality, deposition of an inch of sediment may take many thousands of years, and it may be still more thousands or even millions of years before the sediment has a chance to turn into sedimentary rock. The drying of the paper serves as a simulation of turning sediment to sedimentary rock.

5. Excavate the "fossils." When the paper pile is dry, proceed with "discovery" and "excavation" of the fossils it contains. Begin by cutting away paper from the top of the stack. A sharp knife may be necessary for this, so it may be best to limit the students' participation in this part of the exercise. Explain that since the top layers were deposited last, they represent the youngest rocks, and as you go deeper into earlier-deposited layers, you find older and older rocks and fossils. Keep track of the kinds of fossils you collect from each layer.

This exercise may be extended by organizing the fossils excavated from the paper. Have the students put fossils collected from the same layers together, as they represent fossils of the same age. Refer to the handout "Stratigraphy" in Appendix E (page 94) for ideas on recording stratigraphic positions of the fossils the class collects.

Version 2-paper cups with mud

Materials Paper cups, one for each student or working group; mud of two contrasting colors; bones, shells, leaves, or other possible "fossils;" spoons.

This version is somewhat more realistic than version one in that actual sediment is used. It also has the advantage that each student could have his or her own specimen. It may, however, take a little longer and be more difficult to set up and monitor.

Procedure

1. Add layers of mud to the "lake." Distribute a paper cup to each student, or to each group if they will be working cooperatively. Explain that they are going to simulate a lake in which mud is slowly being deposited. In this lake live plants and animals that fall to the bottom when they die. Add liquid mud to the cup in increments, alternating colors and allowing the mud to settle between each addition. The students may add small shells, leaves, or bones at any point in the sedimentation process.

2. Dry the sediment. The drying of the mud simulates turning the sediment into rock. Drying will take place much faster if the cups are placed in a warm, dry place, even a warm oven, for a few hours. If the mud is fairly soft when dry, the students can excavate their own "fossils.",

Variation Make a small pond in the schoolyard and fill it with muddy water over a period of days. To this sedimentary system have the students add chicken bones brought from home (ask them to remove all traces of meat from the bones and scrub them with soap before bringing them to class). When the pond is full of sediment, let it dry out, and excavate the "fossils." Be sure to keep up the message that geological time is very long and this is only a simulation.

ACTIVITY 2 Making a trace fossil

Message A trace fossil is evidence of activity of a plant or animal. Trace fossils are useful for learning about ancient life.

Materials Shallow trays or pie plates; fine sand or modeling clay; plaster of Paris; carving tools (plastic knives and spoons, popsicle sticks).

Begin by reading the discussion of trace fossils on page 5. When you explain this exercise to the students, it is important to bear in mind the difference between a trace fossil and a mere impression made in sediment by a dead organism. A trace fossil is evidence of the activity of a living organism. Often trace fossils provide valuable information about how an animal lived and interacted with its environment. Sometimes it is not clear which animal was responsible for a given trace fossil.

Procedure '

1. **Create a depositional setting.** The depositional setting is represented in this activity by a shallow tray or pie plate containing a layer of clay or fine, damp sand. If you use sand, it should be fine-grained and cohesive enough (a little clayey) so that it will hold details and not absorb too much plaster. The students can use their imaginations to decide what kind of environment their sand or clay surface represents. This might include a sea or lake bottom, beach, river, or sand dune.

2. **Choose an activity to "fossilize."** The students can use their imaginations to decide what kind of activity their trace fossil will preserve. Ask them to pretend that they are some kind of animal living in their chosen setting, and to think about what that animal might do that would leave a trace in the sand. The student may decide to carve a walking or crawling trace across the surface, or make a shallow burrow (depending on the thickness of the sand layer). Some animals, like earthworms and many different marine animals, even some whales, ingest sediment as they make their way through it, leaving a "feeding trace." The students' trays could be scale models, allowing them to represent a great variety of activities.

3. **Preserve the "trace fossils."** This can be done by pouring a layer of plaster of Paris over the clay or sand. This mimics the natural processes of burial by more sediment and turning to rock. After the plaster hardens, simulating the passage of perhaps millions of years during which the sediment turns to rock, the plaster can be removed. Tell the students that a trace fossil usually has two parts, the bottom part (the clay or sand) and the top part (plaster), the latter in this case being the better preserved. To reinforce the message, have each student prepare a label for his or her trace fossil, giving the name of the suspected trace maker and what activity is represented. Students may exchange the trace fossils and try to create in their minds the activities represented by their classmates' traces.

Variation 1 Look for potential trace fossils in the schoolyard. These might be tracks of people or pets, or even cars, in mud. The students could make plaster casts of these and display them along with an explanation. What kind of activities do these represent? What would have to happen to these tracks for them to become real fossils? If you discovered a trace fossil like this in a rock how would you interpret it?

Variation 2 Another variation on this exercise allows the students to be a little more systematic in their detective work. Have the students clear off an area of bare dirt or playground sand in the schoolyard with rakes or brooms so that no tracks are visible. Return the next day and take notes on what can be seen on that spot. What has happened here in the past 24 hours?

ACTIVITY 3 Replicating fossils with aluminum foil

Materials Two-dimensional fossils or casts; heavy-duty aluminum foil.

This is a simple way for students to make copies of certain fossils. It works best for specimens (or casts) that are reliefs on flat slabs of rock. It will not work with three-dimensional fossils unless only small parts of them are replicated. Specimens in the kit that are suitable for replication using this method are the fish impression, fossil leaf, and dinosaur skin impression.

Procedure

1. **Press fossil details into foil square.** Cut out a piece of heavy-duty aluminum foil slightly larger than the fossil to be replicated. Then press the foil in place over the fossil, molding it into its contours. For specimens with high relief some wrinkling of the foil is inevitable.

2. Trim the **foil replica.** After details are pressed into place, remove the foil and trim off any uneven edges with scissors. For permanence, the foil replica can be glued to a square of cardboard.

3. Complete the specimen. Fill out a label giving the fossil's name, age, and name of the place where it was found.

Field Trip

A first paleontological outing

This field trip is an introduction to paleontology. It may be the first time many of the students have thought about fossils and the rocks in which they are found. Material that is presented is limited only by the imagination and experience of the teacher. Since lesson material for this exercise is generalized, detailed information presented to the class will be determined by the field area visited. The perfect site for a field trip is a known fossil locality. If you are near a national or state park or area of public land, contact their office and ask them about the suitability of their area. Don't overlook places like quarries or gravel pits as possible sites. If these are not feasible consider the alternate field trip below.

Most of the time in the field could be spent looking at examples of fossils and , how they are found, and discussing how these organisms lived and became fossilized. A considerable amount of time will be taken up by students' questions. If they are allowed to collect fossils, the teacher or someone nearby should be knowledgeable to answer questions about the identity of their finds. With a little practice, fossil guidebooks (see references at end of each unit) will help teachers and students identify fossil finds.

One topic of this trip might be the origin of sedimentary rocks, whether or not they contain visible fossils. Seeing rocks in the field is a good way to visualize how sediments are deposited. Turning of sediments to rock over millions of years is a more difficult concept for children to grasp, but after seeing and touching the evidence, students can more easily accept these statements as observable facts. In the field, it is also easier to understand the concept of superposition: sedimentary rocks on top are younger than rocks beneath them. Students then have the basics of relative dating using fossils.

• **Ethics in the field** It is a good idea to bring up the topic of ethics in paleontology on the students' very first encounter with fossils. There is no better place to do this than on their first field trip. Good ethics (for professionals and students alike) encompasses such things as asking permission to explore or collect on public or private land and not disturbing that land any more than necessary. It also means taking careful field notes and properly recording the location of each find for further reference. It is also advisable to learn as much as you can about the fossils you find by reading and talking to experts in the area so that you know the difference between common fossils and rare ones.

• **An alternate field trip** A trip to a local park, river, lake, or seashore could become a study in fossilization. Some questions that you might be able to address on hiking with the students include: What kind of depositional settings are found here? Where is. sediment being deposited and what kind of sediment is it? What kind of animals and plants live here? How many of them have a chance of being preserved as fossils? Do all of them stand equal chances? What would be some ways fossils could be preserved in these settings?

Post-questions

1. **What are some ways that an animal or plant could become a fossil? (Name as many different ways as you can think of.)** *See the box on page 4 for some ways organisms can become fossils.*

2. **What three things are required for a living thing to become a fossil?**
   See the Overview discussion. The three things that are required are, 1 possession of *hard parts, 2 quick burial in a protective environment, and 3 favorable conditions after burial (diagenesis).*

3. **Why is it normally so difficult for a plant or animal to become a fossil after it dies?** *The chances are small that all the conditions will be just right. Not many places have the right combination of depositional setting and possibility of preservation after burial.*

4. **What is the difference between a "normal" fossil (body fossil) and a trace fossil?** A *body fossil is actual remains of hard parts* of *a plant or animal. A trace fossil is evidence of activity of a living thing-no actual remains are necessary.*

5. **Why are fossils important? What do they tell** *us? Fossils are important because they show us what living things were like before there were people around to record them. They tell us many things: what these organisms looked like, what they ate, where they lived, how they interacted. They allow us to piece together the history* of *life.*

6. **Parts of a living thing may be preserved for millions of years in rock. These fossils provide very important evidence of how living things were different in the past. They can never be replaced** ıı **destroyed. What can you do to protect this valuable evidence?** *See the Overview discussion in this unit and in Unit 4, Human Influences. Students and amateur fossil collectors can help conserve fossil resources by reporting finds to professionals in parks, museums and universities.*

7. **Name some national parks or monuments or sites on public land that have fossils. What kind of fossils are they?** *See the list* of *national parks and monuments with fossils in Appendix A, page 68, and the list* of *sites on public land, Appendix 8, page 73.*

Post-site activities

ACTIVITY 4 The fossilization game

Message — It is not easy to become a fossil. Many plants and animals never have the chance to be preserved as fossils.

Materials — You may make copies of the fossilization cards in Appendix E (page 92) or have the class design their own.

The fossilization game is a fantasy and role-playing exercise that helps children understand fossilization processes.

Procedure

1. **Choose an environment.** The game begins with the class or smaller group choosing an environment in which there is a depositional setting such as a lake, pond, stream, river in a forest, sea floor. The students can use their imaginations to describe this setting in as much detail as they desire.

2. Choose roles. Roles that the participants choose for themselves are possible animal or plant inhabitants of the chosen setting. For example, in the aquatic settings possible roles include not only snails, clams, fish, salamanders, turtles, alligators, and other aquatic animals, but also horses, deer, monkeys, rabbits, and birds that come there to drink.

3. **Begin play.** When play begins, the children act out their roles, with each one given a turn to make vocalizations or gestures. For example, a child playing a fish could wiggle his body with a fishlike motion and make gulping motions with his mouth. A child playing a prairie dog might pretend to dig a burrow and make high-pitched barks. They can also interact with each other as they would in their natural environment. For example, the carnivores could chase the herbivores.

4. **"Freeze" and decide the fate of the characters.** At a time determined by the teacher, action "freezes" and the time for possible fossilization begins. The students draw cards which tell their fate: *You are eaten by scavengers. You rot away before you can be preserved. You are swallowed by a crocodile. You are buried by a mudslide and preserved as a fossil.* You can make several copies of the page of cards in Appendix E to use in this exercise. If you make your own, the proportion of "fossilization" cards to "destruction" cards should be small, mimicking the small chance of becoming fossilized in the real world.

5. **Discuss the meaning of this exercise.** When the entire class has drawn cards, discussion can begin. Have each student discuss his or her role as an organism and what happened to this organism after it died. Make a .list of these organisms on the blackboard. Which animals became fossils? Which were destroyed? Remember, the only animals and plants future paleontologists will know anything about are the ones that become fossils. You will become aware of the important question of bias in the fossil record when you compare the list of fossils with the complete list of living animals. Is the list of fossils a good representation. of the living community? Why not?

If time allows, play the game again with the same animals and plants. How are the results similar or different?

ACTIVITY 5 Some parts make better fossils than others

Message — Not all parts of animals and plants become fossilized. It may not be possible to know some details of what an ancient animal or plant was like because many parts of the anatomy may not become fossils.

Materials — Drawings of horse and Stegosaurus skeletons (Appendix E, pages 93-94)

In carrying out the preceding exercises and discussing fossils in the classroom, it should have become evident that fossilization is a rare event. The chances of a given individual being preserved in the fossil record are very small. Some organisms, however, have better chances than others because of the composition of their skeletons or where they live. This also applies to the various parts of organisms. For example, plants and vertebrates (animals with bones) are made up of different parts that can separate after death. The different parts can be transported by currents to different locations and be preserved separately. A fossil toe bone might be found at one place and a fossil rib at another location. We could assume that they are from different animals when, in fact, they came from the same one.

Much information is lost in the fossilization process. Think, for example, of a vertebrate (such as ourselves). Much of what we consider important about our own biology is in the soft tissues, such as skin, hair and internal organs. These characteristics would usually be unknown in the fossil state, because most of the time only bones and teeth are preserved. (There are exceptional cases where soft parts are preserved.) Bones and teeth are not always preserved together. This exercise is designed to get children to think about the quality of information that comes from the fossil record.

Procedure

1. **List facts about a living animal.** The skeleton of a horse is shown in Appendix E, so a horse will be used as an example here. Other possibilities include a cow, dog, cat, or sheep. The list of facts on the horse might include, but not be limited to: large size, fast runner, eats grass, has grinding teeth, has long hair for a mane and tail, whinnies, is intelligent, is sociable %vith other horses, makes a good pet.

2. **What would we know if this animal was extinct?** Refer to the diagram and point out an important generality of fossilization: most of the time, only the hard parts (bones and teeth) are preserved as fossils. Go through the list and ask the class what we would know about the horse if horses were extinct and all we had were fossilized bones of horses. We would know that it was a large animal and could probably make some good guesses about its weight. We would know that it had grinding teeth and could probably guess from that that it ate some sort of tough vegetation, probably grass. The hooves would not be preserved, but the shape of the foot bones would be a good indicator that it had hooves. The skeleton would also be useful to tell us that it was a fast runner. But no details of the hair or skin would be known. Everything about social behavior or vocalization would also have to be guesses.

3. **What do we know about fossils?** Pass out the diagram of the fossil Stegosaurus and interpret it in the light of what we do not know. Use the list you made in discussing the living animal. What paleontologists know comes from studying the hard anatomy, in this case bones and teeth. Anything else is a guess, although in most cases it is possible to base the guess on sound biological principles.

4. **Use your imagination!** As a summary to this exercise, have the class put muscles and skin on the diagram of Stegosaurus that they have. Remember, hair, scales, and skin color are largely the choice of the artist, since fossil bones are no help.

ACTIVITY 6
A classroom museum

A classroom museum can be modeled after Activity 18, A classroom natural history museum, in Unit 4 (pages 56-57). Encourage your students to bring in fossils they or their parents have found. Along with objects created in class, the class may develop quite a collection of fossils and simulated fossils. Gather these objects together for your small natural history museum. Displays or exhibits can be designed and set up by the students. Specimens should be complete with labels giving their name and where they were found. Suitable museum labels can be found as a handout page (page 99) in Appendix E. Pictures of fossils rather than names could be used. Have the students write stories describing their experiences collecting and interpreting the fossils in the museum collection. Fossils could be used for further discussions about what scientists know about the original organism. If enough fossils are brought in, locations of finds could be plotted on a state road map or a map obtained from a local BLM office.

National Parks and Monuments and Public Lands

Fossilization in action

One place where thousands of animals and plants have been preserved as fossils (and are still being preserved today) is Rancho La Brea in Los Angeles, California. Rancho La Brea is not a national park or monument, but it is recognized by the National Park Service as a National Natural Landmark because of its outstanding natural features.

Rancho La Brea is the site of a natural asphalt (tar) seep in which have been found the bones of thousands of animals, as well plant remains. Most of the fossils at Rancho La Brea date from 40,000 to about 4,000 years ago. Over 420 species of animals and 140 species of plants have been found in the tar pits. Only one human fossil has been found: that of a woman who lived about 9,000 years ago.

The most popular explanation for formation of the Rancho La Brea fossil deposit is that animals became entrapped in sticky tar and were unable to extract themselves. Scavengers were attracted by the struggling animals and became entrapped themselves. After death, their flesh rotted away and their bones settled into the asphalt. During the wet season streams deposited sand over the asphalt pools and helped to bury the bones. Thus the three requirements for

fossilization are met: hard parts, rapid burial, and suitable conditions after burial (diagenesis).

Today Rancho La Brea is a park where several small asphalt pools are visible. One pool is enclosed by a building with a viewing platform. There it is easy to imagine becoming trapped in the sticky tar and slowly sinking out of sight.

The George C. Page Museum, a branch of the Natural History Museum of Los Angeles County, was built on the site of Rancho La Brea to house and display the fossils collected from the asphalt. The museum and asphalt pits are located in Hancock Park in western Los Angeles.

See the book *Rancho La Brea: Treasures of the Tar Pits,* edited by John M. Harris and George T. Jefferson, Natural History Museum of Los Angeles County, distributed by University of Washington Press, 1985 (ISBN 0-938644-19-X).

• **Other Sites** Examples of many different kinds of fossilization can be seen in the national parks and monuments and on the public lands. At Florissant Fossil Beds National Monument, fossil plants, insects, fish, birds, and small mammals have been preserved in lake sediments. They were buried in the lake by ash spewed from volcanos about 30 million years ago. Some fossils at Florissant were buried quickly by mudflows triggered by volcanic eruptions. A lake was also the site of fossilization at Fossil Butte National Monument and surrounding public lands in Wyoming.

Floodplains of rivers are often good places for fossilization to occur. Animals may live on floodplains or visit there frequently because there is water available and often trees for shelter. Bones of animals that live on floodplains accumulate over a period of several years and then are buried in river silt by floods. In Petrified Forest National Park in Arizona, floodplain sediments preserve the fossils of dinosaurs and trees. Volcanic ash helped in quick burial of some of those remains. River channels and floodplains were the burial sites of the dinosaurs at Dinosaur National Monument in Utah. Rivers and floodplains were also responsible for preserving the many fossil mammals at Badlands National Park in South Dakota and at the Brown/Howe Dinosaur Quarry near Shell, Wyoming.

I Simon and Schuster's Guide to Fossils, P. Arduini and G. Teruzzi, Simon and I Schuster, 1987. (ISBN 0-671-63132-2) This book introduces paleontology and sedimentary geology for the amateur collector. Its many color pictures of fossils are among the most beautiful available in a book of this kind.

Evolution of the Earth, R.H. Dott and R.L. Batten, McGraw-Hill, 1981. (ISBN 0-07-017625-6) One of the best "standard" historical geology texts. Useful as a general reference, as well as interesting reading on the history of earth and life.

The Fossil Book: A Record of Prehistoric Life, C.L. Fenton and M.A. Fenton, Doubleday and Co., 1989. (No ISBN) A classic of paleontology, this book contains a wealth of information on most groups of fossil plants and animals, marine and terrestrial. The glossary and guide for amateur fossil collectors are valuable accompaniments to the text.

The Field Guide to Prehistoric Life, David Lambert, Facts on File, 1985. (ISBN 0-8160-1125-7) This "concise key to prehistoric animals, plants, and other organisms" is a reference to many different groups of fossils, geologic periods, principles, practices, and accomplishments of paleontology. Its unusual field-guide format, using text and picture boxes, lends itself to browsing.

Fossils: How to Find and Identify over 300 Genera, R. Moody, Collier Books, MacMillan Publishing Co., 1986. (ISBN 0-02-063370-X) A concise introduction to paleontology for a person who wants to look for fossils in the field. Discusses preparation, safety, and proper conduct. Background material addresses modes of fossilization. Color photographs and accompanying descriptive text would be helpful in identification of fossils.

Fossils: A Golden Guide, Rhodes, Zim, and Schaffer, Golden Press, 1962. (ISBN 0-307-24411-3) An illustrated guide for the amateur, especially suited as a first fossil book for children. Shows some of the more common invertebrate and vertebrate fossils.

Geology: The Active Earth, Ranger Rick's NatureScope, National Wildlife Federation, 1988. (ISBN 0-945051-38-7) A good reference for teachers. This book examines how and when fossils form, what they tell about the past, how scientists determine the ages of fossils, origins and uses of rocks, minerals, and fossil fuels, forces that wear down landforms and forces that build them up, and an introduction to plate tectonics. Good classroom activities.

The Illustrated Encyclopedia of Fossils, G. Pinna, Facts on File, 1990. (ISBN 0-8160-2149-X) A lavishly illustrated book displaying a diversity of fossil plants, vertebrates, and invertebrates. Presents a good discussion of fossilization processes.

The Encyclopedia of Prehistoric Life, R. Steel and A. P. Harvey, McGraw-Hill, 1979. (ISBN 0-07-060920-9) A comprehensive summary of fossil organisms, evolution, principles, techniques, and history of paleontology. This book is a useful, semi-technical reference for amateur and professional paleontologists.

Understanding and Collecting Rocks and Fossils, Martyn Bromwell, Usborne Publishing Ltd., 1983. (ISBN 0-86020-765-X) Introduces the amateur to identification of common rocks and minerals. Describes how to prepare for a field trip to collect rocks or fossils. Contains some aids for fossil identification. Introduces geologic mapping. A source of classroom activities in geology and paleontology. Interesting reading for children or adults.

Project Wild Elementary Activity Guide, Western Regional Environmental Education Council, 1988. (No ISBN) A bonanza of classroom and field activities designed to increase awareness of wildlife and their habitat. Many exercises in this guide address themes of adaptation, community, and human influences and could be applied to a study of paleontology.

Exploring Science Through Literature, Level B, JoEllen Moore and Thomas Camille, Evan-Moor Corp., 1991. (No ISBN) Good activities regarding rocks.

Books for children

Digging into Dinosaurs, Ranger Rick's NatureScope, National Wildlife Federation, 1989: (ISBN 0-945051-33-6) A good reference for teachers. It has good background information and activities on dinosaurs and fossils. Among the activities are time line and fossilization exercises and discussion of meat- and plant-eating dinosaurs and modern animals.

The Fossil Factory, Niles, Douglas, and Gregory Eldredge, Addison Wesley Publishing Co., 1989. (ISBN 0-201-18599-7) This book contains good activities for children with fossils, fossilization processes, and collecting.

Fossils: A New True Book, Allan Roberts, Children's Press, 1983. (I S B N 0-516-41678-2) Introduces fossils to beginning readers in grades 1 through 3.

Fossils Tell of Long Ago, Aliki, Crowell, 1972. (ISBN 0-06-445093-7) Describes some of the ways living things can become fossils and tells a story of children's adventures with paleontology. May help children learn why fossils are important.

The Children's Picture Prehistory: Prehistoric Mammals, Our World After the Dinosaurs, Anne McCord, Usborne Publishing Ltd., 1977. (ISBN 0-86020-128-7) A well-illustrated discussion for children of several interesting aspects of fossil mammals. Some ideas for classroom activities. Contains an illustrated glossary.

[redacted]

The How and Why Activity Wonder Book of Dinosaurs, Q.L. Pearce, Price Stearn Sloan, 1988. (ISBN 0-8431-4286-3) An easy-to-read introduction to dinosaurs and some other fossil groups. The text is enhanced with numerous puzzles and hands-on activities.

Video

Dinosaurs, Puzzles From the Past, No. 51046, National Geographic Society, Educational Video Presentations, Washington DC 20036. Excellent 20-minute video about the geological time line.

UNIT TWO: ADAPTATION

Introduction

The National Park Service has a mandate to protect the ecosystems within its boundaries. This includes both modern and ancient environments. Each provides an important story of the earth and how its organisms have responded to change.

The study of organisms from ancient worlds can help us learn about our own modern world. By understanding how ancient organisms lived and died we can gain new insights into how living things cope with their environments today and how their survival (and ours) depend on the consequences of our actions.

This unit introduces students to relationships of organisms, both fossil and modern, with their environment. It will encourage them, through making and recording their own observations about fossils and the rocks in which they are found, to ask questions about ancient and modern examples of adaptation. On short field trips around the schoolyard or neighborhood, students will observe how modern plants and animals are adapted to their environments.

Objectives

Upon completion of this unit students should be able to:

1) discuss what fossils are and what they can tell us about the past;

2) list at least three things that can be learned about ancient environments and extinct organisms by studying rocks and fossils;

3) describe some comparisons that scientists make between fossils and living organisms;

4) stress in their conversation that ancient animals and plants were adapted to their environments just as modern ones are; and

5) emphasize how changes in environment (climate, topography) resulted in extinction of plants and animals in the past and will continue to do so in the future.

VOCABULARY

Carnivore (kar-ni-vore) An animal that eats other animals.

Climate The history of rain, snowfall, and temperature, for an area. The average weather.

Coprolite (ko-pro-lite) Fossilized dung.

Environment Conditions in which an animal or plant lives. Consists of two parts. The physical part includes air, water, climate, soils, and topography. The biotic part consists of all other living things in that environment.

Extinction Extinction occurs when every member of a certain species of plant or animal dies.

Fossil Any naturally-occurring evidence of past life.

Habitat Where a plant or animal lives.,

Herbivore *(her-bi-vore) An* animal that eats plants.

Omnivore (om-ni-vore) An animal that eats both plants and animals.

Paleontologist (pay-lee-on- toko-jist) A person whose job is the study of fossils and ancient life.

Paleontology (pay-lee-on- toPo-jee) The study of fossils and ancient life.

Sediment Naturally-occurring material transported and deposited by water or wind, such as mud, sand, or peat.

Sedimentary rock A rock made of compressed and cemented sediment.

Species (spee-seez; sing. and pl.) A group of closely related plants or animals.

Trace fossil Fossil evidence of an activity of a living thing. Examples: footprint or coprolite.

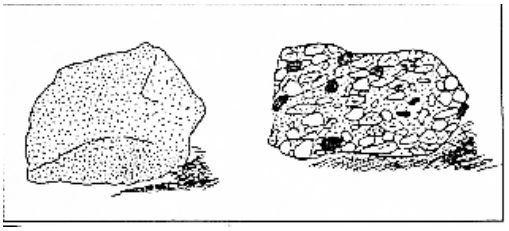
Environments of past and present

The record of past life is more easily understood if we are able to refer to modern living things that we can observe directly. Perhaps the most important message to convey to young students just beginning their study of paleontology is that we can learn much about our own world by studying worlds of the distant past. It is often said in the geological sciences that "the present is the key to the past" (the geological principle of actualism; see A *Trip Through Time* by Cooper, Miller, and Patterson, reference on page 34). It is also true that what we know about the past can tell us a lot about the present.

An important concept in this unit is that of environment. An environment is defined as all the influences, both physical and biotic in nature, which affect an organism. The climate is part of the physical environment as well as the topography, soils, and water. The biotic environment includes all other organisms living in a given environment. Thinking environmentally means that no organism can be considered in isolation from any other element of its environment.

Adaptation is another important topic. Many examples of adaptation of organisms to their environment can be seen in nature. Some of the most successful organisms have very strong specializations for a specific environment. A fish, for example, is adapted to the aquatic environment. It has gills to exchange oxygen and carbon dioxide from water, fins and a streamlined body to swim through the water. It is well adapted to its environment and would be quite out of place on land. As another example, most birds have very specialized adaptations for flight. But with a little thought it will become obvious to students that different birds have unique specializations beyond those required for flight: although both a duck and a hawk can fly well, they are quite different. A duck is adapted for life in the water as well as the air, and has adaptations like webbed feet for swimming and a flat bill for straining food out of the water. A hawk, on the other hand, has adaptations like a sharp beak and talons for grabbing prey, and good eyes that enable it to hunt from the air.

The fossil and rock records



Evidence about ancient living things and their environments comes from studying rocks and the fossils contained in them. Children can make some basic observations pertinent to understanding depositional settings, a basic part of understanding the origin of fossils. One of these is grain size. Coarse-grained sedimentary rocks generally originate in energetic settings like rapidly-flowing rivers. Fine-grained sediments are deposited in less-energetic settings. Students can observe this in modern environments when they compare sediments of a fast-flowing stream with those of a sluggish stream or lake. They can then draw some basic conclusions about the sedimentary. rocks in their collection. You may want to consult a field guide or one of the books listed at the end of this chanter for tips on rock identification.

A similar comparative approach is possible with fossils. Adaptation to environments can be seen in the fossil record as well as in the modern world. Paleontologists rely on comparisons between fossils and modern living things to understand the ways of life of ancient organisms. For example, a wing is adapted for a definite function (flight) and has a structure that can be recognized in fossil bones ac wall ac those of mnriarn birds A hat has a similar structure hilt it is cnm-

Materials included in the kit

slide carousel: environments and adaptations magnifying lenses casts of modern animal bones and fossils: fossil carnivore (blue tag) fossil herbivore, (green tag) fossil omnivore, (black tag) modern carnivore: coyote jaw (yellow tag) modern herbivore: rabbit jaw, (orange tag) fossil fish casts slab of rock from Green River Formation

Optional materials

cameras and notebooks for field trip

posed of a different arrangement of bones. We also recognize bats as fossils. Even if there were no fossil birds or bats, we would still know by their differences in anatomy that these two groups had different ancestors and different histories. The fossil record confirms what we suspect from studying the modern animals. Bird wings and bat wings are called analogous structures because they have similar functions but different origins.

Structures that use the same body part in different organisms and which may be used for different purposes are called homologous structures. For example, the bones in the front leg of a dog match one-for-one the bones in a human arm.

Adaptation and changing environments

Environments are not static things. They are continually changing and have been changing throughout Earth history. Evidence for past environmental change abounds in the rock and fossil records. If change is gradual, organisms can adapt to the change or move to other more suitable areas. Abrupt change is more difficult to **cope with, and** organisms that cannot keep up with it face extinction. At numerous times in the geologic past, there have been widespread extinctions affecting organisms on a world scale. We know that in many cases these "extinction events" were the result of large-scale environmental change, but in most cases the evidence from the ancient record is inconclusive. Thus, for example, reasons for extinction of the dinosaurs at the end of the Cretaceous are speculative. There were probably many causes rather than one.

Extinction is a topic of fundamental importance not only with regard to fossils, but also when discussing modern living things. Largely as a result of human activities, environments are changing today at rates unprecedented in Earth history. Globally, the composition of the atmosphere has been altered by the addition of man-made compounds and carbon dioxide from the burning of carbon-based fossil fuels. This affects the absorption of sunlight, which has the effect of changing the climate on a massive scale. Locally, environments are being irrevocably altered by urbanization practices and the clearing of land for agricultural use at the expense of wildlife habitats. As a result, extinctions are occurring today at rates never before seen. We cannot tell what the long-term consequences of our actions will be. Whether a major event on the scale of the demise of the dinosaurs is in progress is a serious point that we should think about.

Pre-questions

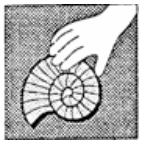
1. **What is an environment?** *An environment is the "world" of a living thing. It includes both living and non-living parts. Refer to the discussion in the Overview.*

2. **What is your environment like? This** *question can be used to start children thinking about how their own world is similar to or different from that of animals, both living and ancient. Get them started by having them describe their home, city, countryside, family and friends.*

3. **What kinds of animals and plants live with you in your environment?**
   Have them describe their natural environment. This is a good question to ask before and after a walk in a neighborhood park.

4. **What is a fossil?** *This question will test the students' pre-knowledge about fossils by encouraging them to come up with examples. If they mention only dinosaurs, tell them that not all fossils are dinosaurs. Challenge them to think of other examples in the coming weeks.*

4. **What can we learn from studying fossils?** *We can learn what living things were like before we were here. Importantly, fossils can tell us about animals and plants that are alive today.*



ACTIVITY 7 Slide presentation

This brief slide presentation has been prepared to help introduce students to the concepts of environment and adaptation. You should prepare them by first introducing those terms and any others in the vocabulary list on page 20 that you think the students do not already know. The slide presentation will then reinforce those ideas.

The black-numbered slides are keyed to the following narrative. Read the text as you show the slides, stopping to explain points or to ask or answer questions. Ideally, this should be done with as much interaction with the class as possible. Let the students contribute their thoughts on the pictures, too.

1. TITLE ..... The environment is the world we live in. An environment has two parts. The first part is the physical part air, water, soil, and climate. The second part includes all the other plants and animals.
2. INTRO ..... There are many different kinds of environments on Earth and different kinds of living things are at home ..... each one. Let's look at a few different environments and some of the animals and plants that live in them.
3. PRAIRIE ..... The prairie,
4. OCEAN SURF ..... the ocean,
5. GLACIER NP ..... the mountains,
6. BIGHORN BASIN ..... the desert,
7. GRINELL LAKE ..... a lake. All are environments. And each is a place where different plants and animals live.
8. BADLANDS NP ..... Some environments are rugged.
9. WYOMING PLAIN ..... Others are flat.
10. BIG TREE ..... Some are cold.
11. FLORIDA PALM ..... Others are warm.
12. KEITH COUNTY ..... They may be dry,
13. ALLIGATOR ..... or wet. Animals and plants have special ways to survive in their environments. These are called adaptations.
14. BISON, YELL NP ..... The wooly coat of the bison is an adaptation that allows it to survive harsh winters and summer heat.
15. PRAIRIE DOG ..... Prairie dogs spend the winter underground in hibernation. They are especially adapted because they can ..... burrow and dig themselves a home.
16. BIRD ……, What special adaptation do birds have? That's right. They can fly. And so most birds are at home in the air. Environments are animals' homes. But other living things are also part of their environments.

17. ANTELOPE ..... Some plants and animals are adapted to compete with the other living things in their environments. Some have horns or antlers for competing with other members of their own species for territory or mates.
18. RABBIT ..... Others are fast runners.
19. KANGAROO
20. PORCUPINE ..... Some animals
21. PRICKLY PEAR ..... and plants have spines for protection.
22. RATTLESNAKE ..... Some have poison, like the rattlesnake
23. SCORPION ..... and the scorpion.
24. GIRAFFE ..... It is also very important for animals and plants to be able to get enough food to live. That's why many living things have very special adaptations for gathering food. The giraffe has a long neck so it can eat leaves from tall trees.
25. ANTEATER ..... The anteater has a very long tongue to collect ants from their nests.
26. CHIPMUNK..... Chipmunks collect food in pouches in their cheeks. There are many other ways living things are adapted to the world they live in. Can you think of some?
27. FOSSIL 1 ..... Animals and plants that lived many years ago were adapted to their worlds just as plants and animals are today. We know about plants and animals of the past because of fossils.
28. FOSSIL 2 ..... A fossil is some evidence of a plant or animal that has been preserved for many thousands or millions of years.
29. PALEONTOLOGIST……..A person who studies fossils is called a paleontologist. Paleontologists learn about ancient animals by looking at shells, bones, and teeth of fossil animals,
30. PLANT FOSSIL ..... and at stems, roots, and leaves of fossil plants.
31. FOSSIL IN ROCK ..... They also learn about what the environment was like by studying the rocks that fossils are found in. A paleontologist uses all information possible to learn about ancient worlds.
32. PARK RANGER ..... You can learn about fossils and ancient environments by visiting a national park or museum. You can ask the people who studied the fossils and rocks of the area to explain about what kinds of animals and plants used to live there, and what the environment was like.
33. SCENIC ..... Studying fossils might make you think how your own environment is like the ancient one. You might also find out that the environment has changed a lot.
34. SUMMARY ..... Fossils are interesting because they tell us about our world long ago. What can you learn from fossils?

ACTIVITY 8
Neighborhood field trip

A hike through the neighborhood, a local park, or a national park or monument becomes an experience in learning about adaptation if the class keeps its eyes open. Every living thing is adapted to its environment. Here is a chance to think about the environment and its physical and biotic parts.

Look at a tree, for example. Consider how this tree is adapted to the environment. Does it lose its leaves in the winter? Why? What does this tree need to survive? What is special about this environment that allows it to survive?

A common wild animal encountered in urban settings is the squirrel. Consider how this animal is adapted to its life in the trees. Its hind feet are specially jointed so that it can hold onto trees. Its teeth are adapted for a variety of foods. Like most rodents, its front teeth are chisel-like and good for gnawing. Its front feet are used as hands to grasp food as it is gnawed on. How would the squirrel survive in an environment without trees?

ACTIVITY 9
Discovering ancient environments

Message Paleontologists learn about ancient environments by studying both fossils and the rocks they find them in.

Materials Rock slab, fossil fish casts, hand magnifiers.

Procedure

1. **Study the fossils.** Pass out the fossil fish casts and the rock slab. Arrange the students in small circles around the specimens so that everyone has a chance to see them up close. Pass around the magnifiers and ask the students to look closely at the impression. Ask the students what they see on the surface of the cast. Most of them will recognize the impression as that of a fish. Explain that the fish.is a cast, but the rock is real. The rock is similar to rock that contains actual fossils. Ask them to describe the rock. Explain that it is a sedimentary rock, that formed when mud at the bottom of a lake settled into layers. When the fish died it sank to the bottom and was buried in the mud. After many years the mud was so deep that the water was squeezed out and the rock became solid.

2. **Travel back in time.** Ask the students to pretend that they can travel.back to the time when this rock formed. Have them guess what the environment is like. Tell them that the sediment that formed this sedimentary rock was deposited in a lake. What kinds of plants and animals lived there? Fish, obviously, and other lake-dwelling animals like frogs and turtles. Other animals that lived on the shoreline became fossils when they fell into the lake. Explain that a paleontologist would study this fish specimen and other fossils to learn about the other animals that lived with it in the lake. Paleontologists could learn about the physical environment by going out in the field and looking at all the sedimentary rocks that were deposited in the lake.

_. **Discuss what paleontologists do.** Tell the students that paleontologists use all the information they can find to learn about the environments of the fossils they find. Assure them that they have just made some important discoveries and when they go out in the field they will have opportunities to make some more.

ACTIVITY 10 Learning about how ancient animals lived

Message	Paleontologists learn about how animals and plants lived in the past by comparing fossils with animals and plants that are alive today.
Materials	Casts of fossil jaws and teeth (carnivore-blue tag, herbivore-green tag, omnivore-black tag); casts of jaws of modern coyote (yellow tag) and rabbit (orange tag); hand magnifiers.

Procedure

1. **Describe the carnivores.** Pass out the epoxy casts of fossil carnivore jaws (blue tag) and have the students look closely at them. Begin by asking them to describe the jaws. They may notice that the teeth are sharp, blade-like, or pointed, or that the incisors look like their own front teeth. Ask them to guess what this animal ate.

2. **Describe the herbivores.** Show them the casts of fossil herbivore jaws (green tag) and again ask them to describe them and guess what this animal ate. Have them compare the two types and suggest possible explanations for the differences.

3. **Talk about what paleontologists do.** Explain that paleontologists can make good guesses about what an ancient animal ate just by looking at its teeth. And that's good, because teeth are often the only part of an animal that is found as a fossil, because they are so hard. In fact, teeth are the hardest part of an animal's body. This is because (the students might like to speculate on this question) an animal's survival depends on its ability to nourish itself: teeth must be effective in food gathering and processing and must last along time-often, as in mammals, for the life of the animal.

4. **Introduce the modern jaws.** Ask the question: How do we know what animals eat and where they live? Explain that we know by direct observation, so we can use these observations to learn about the fossils. Show them the jaws of rabbit (casts with orange tag) and coyote (casts with yellow tag) and ask them to compare them with the fossils they have just seen. Explain that the rabbit is a herbivore (it eats mostly plants), so its teeth need to be grinders to chew tough vegetation. Then explain that the coyote is a carnivore and needs its sharp teeth to tear meat into small pieces. Each animal's teeth fit its way of life.

   The same is true for the fossil animals. We know that the blue-tagged fossils came from a meat eater (carnivore) because its teeth are very similar to teeth of carnivores we see living today. The same is true of the green-tagged fossils (from a herbivore). Paleontologists use comparisons like these to discover how animals lived long ago.

   Omnivores (black-tagged fossil casts) are animals that eat both plants, like herbivores, and animal flesh, like carnivores. Like you, they need a little of each kind of food to be happy. Some carnivores might actually be better called omnivores. Pigs are good examples of omnivores. People have teeth useful for a variety of foods and are also examples of omnivores. Omnivores can often live in a variety of different environments and under a range of conditions, because they like to eat so many different things. But omnivores often have teeth that look like carnivores or herbivores, and for that reason it might be difficult to detect an omnivore known only as a fossil.

Variations
Study of adaptation is not limited to vertebrate fossils, of course. It is not always so easy to draw conclusions about whether many fossil invertebrates were carnivores or herbivores by looking at their remains, but many interesting observations can be made.

Fossil bivalves, for example, show a range of adaptations that make it relatively easy to determine lifestyle. Mussels are thin-shelled and blade-like, adapted for burrowing in mud or sand. Oysters are strong and thick-shelled and cement their shells to rocks, adaptations for life in the surf. Scallops have light, streamlined shells used for swimming. Some mussels extend threads out from their shells to attach themselves permanently to rocks.

Field Trip

yearning about adaptation from fossils

A field trip to a fossil locality can be an eye-opening experience for school children. They will collect all manner of curiosities, eagerly roaming beyond the earshot of the teacher and forgetting about the scientific goals of the day. Maintaining order will be the biggest challenge for the teacher. One way to make this job easier is careful planning.

Planning a field trip entails not only having distinct goals in mind, but also giving jobs to the students that will help in carrying out these goals. Thus, you should first state the goal of this field trip, "learning about adaptation from fossils," before leaving on the trip. Then ask the class to come up with ways that they can help in the project. Here are some ideas for dividing the responsibilities among the students.

1. Writing a road log or journal
A road log is a complete description of the itinerary of routes and stops in a field trip. Writing the log will be quite a bit of work and will require considerable help from the teacher, but it will be a big help in letting the students know what to expect.

The simplest type of road log is in a narrative form: "Leave Jones School and drive north on Highway 10 to the intersection with Highway 20. Turn right. Drive 12 miles to Smith Company Quarry. STOP 1. The Smith Company mines a rock called the White Mountain limestone at this quarry. It is Mississippian in age (280 million years old) and contains lots of fossil corals . . . ." Obviously some previous knowledge of the trip is necessary; it is up to the teacher to supply this information. Pre-running a trip of this sort where the class will be looking at rocks and fossils in the field is absolutely essential. Many books on regional geology or paleontology contain road logs that can be adapted for elementary-school use.

Taking notes
It is important to keep a record of everything that goes on when in the field. This is an important part of professional paleontology and geology. Assign small groups of students to keep notes on the different aspects of the trip. After the trip the students could compile their notes into a single field trip report. One group should be responsible for writing down where you visit and names of people you talk to. Another group could keep a record of fossils seen (or collected, if appro-

priate). Students working on the fossil list should write down the various adaptations of the fossils they record. For example, *"Exogyra,* oyster with very thick shell, probably to protect it from predators and strong waves. We think it was also adapted to sea water because it looks like modern oysters."

3. Photographing the trip Photographic documentation is another need of a carefully-run scientific expedition. It is also important to keep written notes of what was photographed and when photographs were made. These photographs can become a part of the field trip report.

• Professional help Planning and executing a field trip will be much easier if you can take advantage of someone who is familiar with the place of interest, especially if that person is trained in paleontology and has experience in education. That description fits guides and rangers at many national parks and natural history museums throughout the country. BLM resource specialists and interpreters may also be able to help. While the trip is in the planning stages, be sure to mention to your guide that you are studying adaptation and would like to see some examples of adaptations for specific ways of life, if any could be found. That way, he or she will have time to think about your class goals and to find some material to help illustrate what you have in mind.

On any field trip there will be numerous opportunities for diversion from the main theme. Depending on the situation, it may be best to stick to the theme until your major goals are accomplished, then handle the other interesting points.

Post-questions

1. **What are the two parts of an environment?** *The Overview discusses the two parts: 1, the biotic (living) part, composed of all other organisms living there, and 2, the non-living physical part.*

2. How are fossils important to us? Fossils *are important to everyone because they tell us the history of our common past. Studying* fossils *helps us understand the world around us.*

Questions 3, 4 and 5 would be good questions to pose to your guide when you visit a park or museum.

3. What kind of animals and plants lived in the past at the national park, monument, or area that you visited? What do these fossils tell us about the environment at that time? Has the environment changed? How is it different?

4. How are the fossil animals and plants of the place you visited different from the ones living today in that same area?

5. Could you find places where the environment today is similar to the ancient environment at your field trip site? Where? *After your visit, you may get more ideas by studying the different environments of the world in magazines such as* National Geographic.

5. How do we know what ancient animals were like? *The main way scientists learn about ancient animals is to study their remains as* fossils.

7. **What happens to an animal or plant when the environment changes?**
Some animals and plants may be able to live under a range of conditions and can survive changes. Others are less tolerant of changes and may have to move away. If an anima! or plant can neither adapt nor move away, then it will go extinct.

8. **What are some ways that animals or plants can become extinct? Loss**
of habitat (a place to live), change in climate (becomes colder or warmer, wetter or drier), competition with other species for food or habitat, overpredation (killed off *by predators).*

9. **List some animals that are extinct. How many of these have become extinct recently?** *There are literally thousands* of *possibilities. Any animal or plant known only as a fossil, for example: dinosaurs, giant ground sloth, woolly mammoth, trilobites. Others have gone extinct in historic times: the passenger pigeon and dodo bird.*

10. **What are some things that humans do to the environment that might be bad for living things (including us)?** *Most children are aware* of *current environmental problems such as air and water pollution and waste disposal. Some might mention specific things like CFCs in aerosol cans, using too much water, or unnecessary driving.*

Post-site Activities

ACTIVITY 11
Compiling a field trip report

To maximize learning from a field trip it is a good idea to have the class compile their findings in some form when you get back. This is also an opportunity for discussion and cooperation among the students.

Articles to include in a field-trip report include the road log, lists of fossils and their adaptations, and photographs with explanations. You might also include publications from parks, museums, and public lands that you visited.

ACTIVITY 12 A picture story: How am I adapted to my environment?

Have the students each create a picture story from the point of view of a plant or animal (ancient, perhaps something learned on the field trip, or modern). Ask them to describe their environment in drawings: What is the environment like? What other kinds of plants and animals live with you? What are your special **adaptations that allow you to survive** in this environment? What do you like to eat? Are you a carnivore, herbivore, or omnivore?

After the students complete their drawings of their animal or plant at home in their own environment, ask them to do the picture story again in a "foreign" environment. Perhaps they could swap environments with a classmate. Most of these organisms may be unhappy, to say the least.

Follow up this exercise with questions, such as:

1. What are your chances of survival in this foreign environment? Why do you think so?

2. If you cannot live in this new environment what will happen to you? Have the children discuss chances of their survival. How likely is it that an animal would already have adaptations that would allow it to survive in the new climate? What would those adaptations be?

ACTIVITY 13
Discussing adaptation

Some of the best examples of adaptation are seen in adaptation to climate. Using pictures of different environments of the world, begin by talking about extreme environments. Show the class pictures of the arctic or antarctic and discuss the kinds of adaptations that are necessary to live in such a climate. Next discuss deserts such as the Sahara, the tropical rain forest of the Amazon Basin, the Great Plains of North America, coasts, salt marshes, mountain streams, alpine meadows. Each of these environments presents certain challenges to the organisms that live there, yet most of them contain a wealth of plants and animals that survive quite well under extreme conditions. By discussing these organisms in terms of their adaptations the class will gain an appreciation for their own environment.

This activity can be made into more of a cooperative exercise for the students. Have them bring old magazines from home *(National Geographic* and other natural history publications are especially useful). Go through the magazines in class looking for pictures that show different environments. Try to get a sampling of different extremes of climate and topography.

Change in environments is another important topic to discuss. It is sometimes easy to take the world's present environments for granted and assume that they have always been that way. But we know that is not true. Environments have changed in the past and they are always in the process of changing in some way. Environmental change is difficult for humans to understand because it often takes place so slowly that direct observation is difficult. Even the rapid changes that are taking place today as a result of human activity are hard to see. The fossil record contains a compressed view of many millions of years during which environments changed just as they do today. Change in the fossil record is therefore relatively easy to see.

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Some topics that the class might cover with regard to environmental change include changing climates and the results of rapid climatic change. Consider each of the environments discussed when the class talked about adaptation. What would happen if that climate suddenly (in the course of years or decades) became much warmer or cooler? Related to this is the food supply. Herbivores rely on vegetation that lives in their environment. Plants are very sensitive to climate. What happens if a herbivore's favorite food disappears? What happens then to the carnivores that depend on that herbivore for their food supply? The discussion ex>nds to include the entire food web.

Present-day climate change is taking place on a large scale. The phenomenon of global warming from burning of fossil fuels is a topic of much public debate. Do the students understand the cause and effect relationship between driving a car and warming of the atmosphere? Burning of gasoline or any fuel containing carbon causes carbon dioxide (COz) gas to be released into the air. Carbon dioxide allows sunlight to pass through it and warm the Earth, but it does not let the heat radiate back into space. The more carbon dioxide in the atmosphere, the more heat is trapped. This causes the air over the whole Earth to warm. If the air becomes warmer everywhere, what effects will this have? What about the large ice caps that exist on Antarctica and Greenland? If all this ice melted, the oceans would rise several hundred feet and drown coastal cities. How many big cities near sea level can the students name? Look at a map for help.

Destruction of forests, much of it in the tropical (low-latitude) areas of the world where a very large number of plants and animals live, is responsible for the ongoing extinction of many thousands of species of plants and animals each year. The relationship between human activities and extinction is an important one to understand. So is the importance of maintaining the world's diversity of life. The class might discuss what their own stake in this crisis is and what they can do to help.

National Parks and Monuments
And Public lands

Ancient adaptation

Examples of how ancient plants and animals were adapted to their environment can be found wherever fossils are well preserved and where evidence for the ancient environment is also present. In several national parks and monuments this information is interpreted for park visitors.

• **Stromatolites** Some of the rocks in Glacier National Park (in northwestern Montana) contain examples of some of the oldest fossils known. These fossils are strange cabbage-like mounds called stromatolites. The stromatolites in Glacier are at least 1.4 billion years old. Stromatolites form in quiet, shallow water by growth of mats of blue-green algae. Tiny filaments in the algal mat trap mud. Then the algae grow another layer on the mud. Growth is usually not uniform, but usually occurs at a faster rate in some areas, after time causing cabbage-like mounds to appear.

Stromatolites were more common 1.4 billion years ago than today because there were no "higher" animals such as snails or fish to feed on the algal mats. Thus, the blue-green algae were well adapted to life in the shallow sea and sometimes were able to form spectacular mounds. These structures, stacked one on the other in the rock unit called the Helena Dolomite, now make up entire mountainsides in Glacier National Park.

Stromatolites are also found in Fossil Butte National Monument and surrounding public lands in southwestern Wyoming. But we know that the rocks at Fossil Butte are only about 50 million years old. There were plenty of animals around at that time that would have eaten algal mats before they had a chance to form stromatolite mounds (see discussion of Fossil Butte in Unit 3, page 48). Clearly, then, most of the animals must have been somehow excluded from areas where stromatolites formed. What kind of environment was this to which primitive algae were adapted, but no higher animals? It appears that stromatolites formed during times when the lake was very salty. No fish or invertebrates could survive in the salty water and so the tough blue-green algae thrived, just as they did in the Precambrian, 1.4 billion years ago.

References for further reading

Search for the Past: An Introduction to Paleontology, J. R. Beerbower, Prentice-Hall, 1968. (No ISBN) An older, but comprehensive, introduction to paleontology. Discusses principles. Illustrates most groups of invertebrate and vertebrate fossils.

Dinosaurs and their Living Relatives, The British Museum (Natural History), 1979. (ISBN 0-521-26426-X) Introduces cladistic taxonomy-how scientists classify living things on the basis of shared characters. Guides the reader using cladistic reasoning to discover the relationships of dinosaurs.

Ancient Environments, L.F. Laporte, Prentice-Hall, 1979. (ISBN 0-13-036392-8) Discusses sediments and sedimentary environments and how they relate to the environments of living organisms. A moderately-technical account of how paleoecologists reconstruct ancient environments.

The Ecology of Fossils, W.S. McKerrow, The MIT Press, 1978. (ISBN 0-262-13144-7) This book depicts communities of organisms in a chronological series of block diagrams from the Precambrian to the present. Most of the diagrams are cutaway views of the seafloor since the book's emphasis is on the marine, but some land and freshwater communities are also shown. Although technical in nature, this book would be fascinating to read by almost anyone interested in fossils or paleoecology.

A Trip Through Time: Principles of Historical Geology, 2nd edition, John D. Cooper, Richard H. Miller, and Jacqueline Patterson, Merrill Publishing Co., 1990. (ISBN 0-675-21134-4) Discusses principles including actualism (page 177).

• Books for children

Be an Animal Detective, Steve Parker, Derrydale Books, 1989. (ISBN 0-517-68023-8) This book is about modern animals, but has discussions of adaptation that will be useful in understanding some concepts in paleontology. Could be used for children in grades 2 through 5.

Protecting Endangered Species, Usborne Conservation Guide, Felicity Books, EDC Publishing Co., 1992. (ISBN 0-7460-0608-X) Discusses modern endangered species. This book would help children compare the fate of modern endangered animals with animals known from fossils that have been extinct for millions of years. Best for children in grades 2 through 4.

The Usborne Book of Prehistoric Facts, Annabel Craig, Usborne Publishing, Ltd., 1986. (ISBN 0-86020-9733) A whimsically-illustrated collection of isolated "amazing-but-true" facts and lists about ancient life.

[redacted]

Dinosaur Bones, Aliki, Crowell, 1988. (ISBN 0-690-04549-2) Discusses how scientists, studying fossils, provide information on how dinosaurs lived millions of years ago.

Dinosaurs and Other Prehistoric Animals, Tom McGowan, Rand McNally, 1972. (ISBN 0-528-82078-8) A series of engaging stories about some of the better known dinosaurs and fossil mammals. Arranged chronologically from the earliest dinosaurs to the cave bears and mammoths of the Ice Ages.

A Field Guide to Dinosaurs Coloring Book, Roger Tory Peterson, John Kricher, and Gordon Morrison, Houghton Mifflin, 1989. (ISBN 0-395-49323-4) Presents coloring dinosaurs as a challenge to children to guess what dinosaurs might have looked like. Discusses other animal and plant fossils in the context of Earth history. Contains a considerable amount of information on many kinds of fossil organisms.

Video

Dinosaurs, Puzzles From the Past, No. 51046, National Geographic Society, Educational Video Presentations, Washington DC 20036. Excellent 20-minute video about the geological time line.

UNIT THREE: COMMUNITY

Introduction

Few places on Earth preserve communities of ancient organisms where diversity can be observed. The National Park Service and the Bureau of Land Management preserve and protect some of these areas, which serve as outstanding windows into the past.

This unit extends the concepts learned in the adaptation unit by introducing the idea of ecological roles and interactions. As in the previous units, students will be encouraged to draw conclusions about the ancient world of fossils from their own modern world and experiences.

The kit contains examples of fossil herbivores, carnivores, and omnivores, and jaws and teeth of some modern animals the children are familiar with. After the teacher and class discuss how to tell an animal's way of life by looking at its fossil remains, especially its teeth, the students will classify the fossils according to ecological role. Then they will discuss how these animals fit into the ancient food web. Under the teacher's direction this will lead to a discussion of competition and interdependence.

A computer model provides another way of exploring interactions between members of a community. The simulation game used in this unit allows students to create their own scenarios involving modern or ancient ecosystems and experiment with the balance between predator and prey species.

Materials included in the kit

floppy disks for IBM and Apple computers with simulation software casts of fossil and modern herbivores, carnivores, and omnivores

Optional materials

colorful string, yarn, or flagging tape, slips of paper numbered from 1 to the number of students in the class, bowl for numbered paper slips

Objectives

Upon completion of this unit students should understand the dual concepts of ecology (modern) and paleoecology (fossils) and should state in their discussions some similarities between modern and ancient ecosystems. They should be able to:

1) give examples of ancient ecosystems from the fossil record of a National Park System unit or area of public lands;

2) understand what food chains and food webs are and be able to cite a . particular example from a national park or monument or public lands;

3) discuss predators and prey species by giving both ancient and modern examples; and ..

4) understand diversity and how it is important for our own survival. They should be able to cite ways that biological diversity is beneficial to survival of ecosystems and for society.

VOCABULARY

Diversity The number of different kinds (species) of living things present in an ecosystem. Sometimes called biodiversity.

Ecology (ee-koPo-jee) The study of organisms and their interactions with their environment (study of ecosystems).

Ecosystem (ee-ko-sis-tem) A description of organisms and how they interact with their environment.
A progression from plants, which make their own food from sunlight, to herbi vores, which eat plants, to carnivores, which eat herbivores.

Food web How plants, predators, and prey interact. "Who eats whom." A way to describe linking of several food chains.

Organism Another name for a living thing: plant or animal.

Paleoecology *(pay-lee-o-ee-koEo-jee) Study* of ancient ecosystems as seen through the fossil record.

Predator An animal that hunts for its food.

Prey An animal that is the food source for a predator.

Overview

Community interdependence

A community is a group of populations of plants and animals living in the same area. It is possible to study isolated populations of plants or animals, or even individuals, but looking at the whole community gives scientists useful insights into how ecosystems function.

Each of the different organisms that live in a particular community is in some way dependent on all the others. This is called community interdependence. People often find out about how plants and animals are interdependent when they change one part of a community, only to discover that many other parts are also affected. For example, elimination of a prey species might cause a decline not only in the population of its major predator, but also in other animals used for prey.

Changes in the physical environment can cause important, and often unforeseen, changes in habitat. Damming of the North Platte River in Nebraska resulted in near elimination of spring floods, a "smoothing out" of flows. This allowed trees to colonize the sandbars in the river which had previously been swept clean of vegetation every spring by floods. Those sandbars were nesting habitat for wading birds. Loss of that habitat caused a drastic reduction in the population of those birds while it created a different habitat for other plants and animals.

Food webs

Food chains and food webs are ways of thinking about communities. All members of a community are linked together by a series of steps that involve eating and being eaten. This is called a food chain.

The bases of food chains are green plants, which make their food from sunshine by the process of photosynthesis. Next are the herbivores that eat the plants. Predators, who make their living by hunting and eating herbivores, are at the end of food chains. Food chains also include decomposers, such as bacteria and fungi, that recycle dead organic matter (from plants and animals) into the soil where its nutrients can be used by plants to start the cycle over again. A simple food chain might be:

grass - • grasshopper ~ mountain bluebird

In this example, the grass is eaten by the grasshopper who is eaten by the mountain bluebird. Simple food chains rarely exist by themselves. Many animals feed on several types of food. For example, foxes eat mice when they are abundant, rabbits when mice become scarce, berries when they are ripe, then grasshoppers in the fall. Because of complex eating habits like those of the fox, communities consist of interconnected food chains called food webs.

Each part of a food web depends on the other parts for energy to live. The source of energy for all life on Earth is sunlight. Plants get their energy from the sun, and when they are eaten, pass on stored energy to the herbivores that eat them. The herbivores then pass on some of their stored energy when they are eaten by predators. After being converted to other forms, the energy is effectively used up. It must therefore be continually supplied to the food web to keep it running. This shows just how important plants are in maintaining life.

Biodiversity

Biodiversity, or simply diversity, is a measure of the variety of different organisms that exist in a community. Species diversity is the number of different species living in a certain place. Ecosystem diversity refers to the number of different ecosystems in an area. An ecosystem includes a community of plants and animals in its physical environment. Ecosystem diversity happens where interactions between different communities and different parts of the physical environment occur in the same area.

When part of the environment is changed, as through loss of habitat, decrease in diversity can occur. For example, when a population of an organism runs out of places to live, it may die off. The more diversity in an area, the less any given change will affect the whole. Deep changes may cause the loss of an entire ecosystem.

If you think about how a food web functions, that is, energy flowing from plants through animals through decomposers and back to plants, the importance of diversity becomes clear. An ecosystem cannot function unless there are enough of all the parts to keep the system functioning.

Biological diversity is also important in more direct ways for functioning of human society. We, like other living things, depend on the living and physical environment for sources for food, medicine, and building materials. New medicines, for example, are continually being discovered by scientists working with plants. and animals found in tropical rain forests. All of our food comes from living things originally found in nature. Both medicine and agriculture must keep going back to nature to improve their products, products without which we could not live. Our survival depends on having well-working ecosystems, and ecosystems in turn need all their parts to exist.

Paleoecology

Paleoecology is the study of ecosystems of the past through the fossil record. Paleoecologists use fossils and other information in the rocks to discover relationships between extinct animals and plants and their environment. Sometimes they make comparisons with modem ecosystems. It is useful to collect as many fossils as possible to get as good a picture as possible of the complete ancient ecosystem. For example, paleoecologists can learn about ancient diversity by counting the number of species they find as fossils from an area. But a few fossils will not be enough to really tell how many different species were present. Large samples give a better picture not only of diversity, but also of how much variation occurs in a given species.

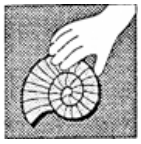
Paleoecologists have been successful in reconstructing the ancient ecosystems of many places for different times in the past. An example of a well-known ancient ecosystem would be the Miocene (about 25 to 5 million years ago) of the Great Plains. The "good" fossil record of the Miocene shows numerous large mammals living on the plains. During the early Miocene there were more animals (like deer) that ate leafy vegetation than those that ate grass. But later in the Miocene grasses spread over the Great Plains and grazing mammals (like horses) began to dominate. Evidence from the fossil plants tells us that the climate became cooler and dryer during that time. Paleoecologists believe that the Great Plains region during the Miocene was very similar to the grasslands of Africa today. A good place to see and appreciate the diversity of Miocene fossils is at Agate Fossil Beds National Monument in western Nebraska.

Pre-questions

1. **Where does your food come from?** Ask *this question at the beginning, and again at the end, of this unit. The bottom line is that our food comes from the sun: plants we eat (grains, fruits, and vegetables) get their energy to live from sunlight; animals we eat get their energy from plants.*

2. How can a paleontologist learn about the **community of plants and** animals living at times in the past? *Many times paleontologists find the plants and animals that lived in the past fossilized together in one place. They find clues in the rocks about the physical environments of the past.*

Pre-site activities



ACTIVITY 14 Computer Simulation: Predator-Prey Interactions

Ecologists sometimes use computers to run mathematical models that describe what happens to communities of plants and animals under certain controlled conditions. These models allow them to make predictions about the real world. Comparison with real-world observations then allows them to improve the model. Computer models are also useful in helping to understand ancient ecological situations. However, this particular. model is not typical of one that paleontologists could use, because continuous fossil records, accurate on the order of years, are extremely rare.

The model included in the teaching kit is similar to a model developed in the 1960s by ecologists. This version is very user-friendly and was designed especially for children. It uses simple mathematical relationships between the number of predators and prey in an area to predict how many of those animals will be in the same area at a later time. The mathematics is not visible to the user, but could be understood and probably modified by gifted children.

The system simulated could be a forest where foxes and rabbits live and interact, a meadow with ground squirrels and hawks, or a lake with herbivorous and carnivorous fish. Of course, the simulation is not limited to a modern scenario. It could just as easily be a Jurassic forest with herbivorous *Stegosaurus* and predaceous *Allosaurus,* or some other scene from the past. The program allows students to make their own decisions about the scenario and to follow changes in the modeled situation from year to year.

Running the simulation

The program is designed so that children who can read will be able to run it with little assistance. Versions for IBM and Apple II computers are included. Starting the program differs slightly depending on which computer is used. Follow the start-up instructions for your computer, next page.

DOS (IBM compatible): Insert either the 3 1/2 inch or 5 1/4 inch floppy disk in a disk drive (A or B) and close the door. Select that drive (type A: or B:) and then type "predator„ followed by the ENTER key.

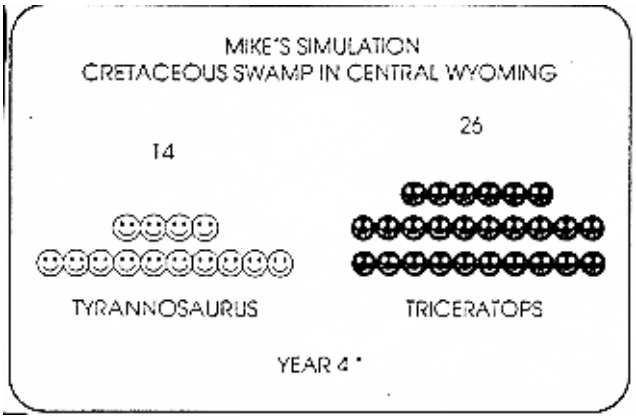
Apple: Insert the floppy disk, then either turn on the computer or type controlcommand-reset to boot up. The program will start automatically.

The program will guide you with a series of messages and prompts. A run session might look like the following example. In this example, the student's keyboard input is shown in italics.

> Hello! This is a model of predator-prey interactions. What is your name?
> *Mike*
>
> Hi, Mike. The computer is ready to do a simulation of predators and prey to show how they depend on each other for survival. A simulation is a sort.of game that might be true. But to make this game realistic, the computer needs your help. You need to use your imagination to make some decisions (computers don't have imaginations). Are you ready? *yes*
>
> First, we need a setting, a place for the story to take place. This could be a forest, a meadow, or a jungle 70 million years ago in the Cretaceous. Use your imagination! Describe your setting on one line. Then press the ENTER key. *Cretaceous swamp in central Wyoming*
>
> Thanks, Mike. Now we need a predator. What is the name of the predator in this story? *Tyrannosaurus rex*
>
> How many Tyrannosaurus vexes should we start out with? 4
>
> Good. Now, what is the prey? What does a Tyrannosaurus vex like to eat?
> *Triceratops*
>
> Now, how many Triceratopses should we begin with? 12
>
> Great! Now here's the story so far: The setting is a Cretaceous swamp in central Wyoming with 4 Tyrannosaurus vexes and 12 Triceratopses. When we're ready to go, the computer will fast-forward a year at a time and show you how many Triceratopses and Tyrannosaurus vexes are able to live in the Cretaceous swamp in central Wyoming. How many years do you want it to run? 20

Very good, Mike. Now we're ready. When you see the flashing star at the bottom of the screen, that means the computer is ready to go on with the next year. When you want to continue, press any key. Let's go! Press any key to continue.

The simulation then proceeds by showing graphically the number of individuals of the prey and predator that are present at the start of the simulation and at the end of each simulated year. A screen for a given year might look like this:



In this example, after four years, the predator is represented by 14 individuals and the prey by 26.

After the final year is done, the program will ask whether you want the computer to print your results. If a printer is connected to the computer, you may answer yes and the program will print out a summary of the whole simulation for the participant to keep.

Hints and recommendations

The purpose of a computer model like this one is to isolate critical parts of a known system and "see what happens" when some parts of the system are changed. It is designed for experimentation; there are no "right" or "wrong" answers. There are, however, some results that more than others will be similar to those encountered in the real world. Each student should therefore be allowed to try several different sets of inputs to compare the results.

We recommend that students start out with fairly small numbers of predators and prey and that the numbers of prey and predators are close. Then they can begin to experiment and ask questions such as the following: What happens when there is a large number of prey but very few predators? How about lots of predators and few prey? What are the differences when I use a large number of animals versus a small number? Why is there a cyclical (up and down) behavior of both predators and prey? Which one "leads" and which one "fags?" What are the conditions that encourage the most stable situation (smallest fluctuations in population)?

Perhaps the most important question the class should be asking is "Why does this system behave the way it does?" This is a simple model and the short answer to that question is that the number of predators the system can support is a function of how many prey are available. The number of prey in turn is dependent on the balance between their relatively high birth rate and predation pressure. Cyclical behavior results from the time lag between these pressures and their responses. Bear in mind that in the real world there is no environment limited to only one predator and its prey. Real ecosystems are complex and not isolated from each other. But then, they are much more difficult to study than this simple model.

ACTIVITY 15 A food web in the classroom

Message **A** food chain is a line from a plant through a herbivore to a carnivore. All food originates with green plants that make their food from sunlight. A food web is a complex of interconnected food chains.

Materials Colorful string, yarn, or flagging tape (cut 2-ft. lengths for each class member; have several longer pieces available); slips of paper numbered from 1 to the number of students in the class; bowl for numbered paper slips.

Participating in a simulated food web is one way for students to understand how complex the interrelationships in natural communities can be. This exercise starts out with simple food chains devised by the students with the help of the teacher. The food chains are then linked in meaningful ways chosen by the participants into a food web. This exercise should be done in a large open space such as a playground or gymnasium.

Procedure

1. **Think of some food chains.** Write them on the blackboard. Remember, all food starts with green plants-the only living things that can manufacture their food from sunlight. Next come herbivores, animals that eat plants. Then, carnivores, animals that eat herbivores. Most of the food chains will have three links, but some can have as few as two, or more than three. Since each link will be represented by a student, you need to think of enough food chains for the whole class. I f there are 30 students in the class, you **will** need about ten food chains. Here are some examples:

willow---- moose -----wolf
grass ---------grasshopper--bluebird
wild oats ------deer mouse----fox
chokecherry ---deer -------mountain lion
pondweed------carp--- ---black bear
sagebrush -----pronghorn ----coyote
algae - ----snail ---- -bass ----------pelican
plankton -------shrimp- -whale
corn ----------pig--------- human
alfalfa -------rabbit --------bobcat
oak (acorn) -----squirrel -----eagle
grass seeds ----prairie dog ---ferret

2. **Choose roles.** When there are food chains with enough links for all students, assign a link to each student. Do this by having them draw numbered slips of paper from a bowl. Then assign number 1 to the first link you wrote on the blackboard, and so on.

3. **Build food chains.** Have each child playing a plant to hold one end of a string (or tape). Give the other end of that string to the herbivore that eats that plant. Next, give another length of string to the child playing the herbivore (in the other hand) and the other end of that string to the carnivore in the food chain. Do this for each food chain.

4. **Build a food web.** Some of the students may be thoroughly involved in their roles and see that there are things in other food chains besides their own that they would like to eat. If so, link the eater with its food. Do this systematically by starting with the carnivores, then the herbivores. Don't leave out the plants-ask them if there is an animal in another food chain that might like to eat them. Ask the participants to choose a third, then a fourth, food item to link with. This could go on for even more steps, but you will probably run out of string and patience before then.

4. **Look at your food web.** Announce that the class has just constructed a food web. Scientists who study how plants and animals live together in their environment (ecologists) have a big job trying to understand all the interconnections (strings). Imagine how hard it is to understand the many interconnections in an ecosystem of the past from fossils.

Field Trip

Reconstructing ancient ecosystems

One of the most exciting parts of paleontology is reconstructing ancient ecosystems and animals and watching extinct plants and animals come to life in their natural world. Paleoecology can be a fascinating exercise for children, but doing a paleoecological exercise with real fossils found in the field is probably beyond the capability or desire of most teachers. This is where the assistance of local museums or parks will be most helpful.

Ask a representative of a park or museum if he or she can help you in your study of ancient ecosystems. Some institutions will be able to supply you with publications written for the general public on local paleoecology. Or maybe all that is available is a list of fossils collected in an area. This basic information can be a starting point for a class project. Prepare the class for the field trip by summarizing the information available. After the trip the students will be eager to talk about all that they have learned.

Try to learn as much as possible about the place and time you are studying. Have the students keep track of this information in a "paleoecology journal" kept just for this purpose. Information should include: where the area is (have the class make a map), when this ecosystem existed (include part of a geological time scale drawn by the students), what kinds of plants and animals lived there, what the vegetation was like (drawings), and who were the predators and prey. Also include, if available, drawings and writings describing how the animals and plants of this environment were fossilized.

More elaborate paleoecological reconstructions are possible if the time and energy of the teacher are sufficient. Possibilities for art projects abound. Have the class make clay sculptures of the plants and animals of your ecosystem in approximate relation to their actual abundance. The sculptures could then be displayed on a surface painted to took like a forest floor, grassland, or desert. Topography, such as mountains and coastlines, could also be sculpted and placed on the landscape. Many details of the paleoecology will not be known; let the students use their imaginations to supply them. Real paleoecologists are often faced with similar situations where they must use their best guess.

Post-questions

Think about the fossils of the place you visited on your field trip that lived together. Which ones are predators? Which are the prey? Are there some that you cannot tell? *Questions 1, 2 and 3 should be posed to your guide when you plan your field trip. Publications on well-researched fossil localities may also provide this type of information.*

Construct a food chain for the fossil animals and plants you are studying. *See no. 1. Remember that plants are at the bottom of food chains, herbivores come next, then carnivores.*

With the help of your classmates, construct a food web for the animals and plants that lived at the time of the fossils you studied on the field trip. *Remember that a food web consists of interconnected food chains.*

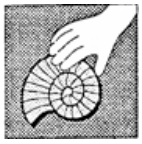
In what way does a predator species depend on its prey? *A predator depends on its prey for food to live.*

In what way does a prey species depend on predators? *A predator takes mostly weak, sick, or old members of prey species, and in doing so strengthens the bloodline of the prey by assuring that the strongest survive.*

Where does your food come from? (Hint: think of a food chain. Vegetables and grains you eat come directly from green plants that get their food from sunlight. *Meat you eat comes from animals that eat green plants.) The sun. See Pre-question 1.*

How healthy would an ecosystem be if many of its parts are missing? For example, what if there are very few predators? *An ecosystem with missing parts will be in trouble because all the parts depend on other parts. A shortage of predators may result in too many herbivores (prey). There might not be enough plants for them to survive the winter.*

Can you think of an example of an unhealthy ecosystem? *There are many possible examples: a polluted lake, a forest with all the trees cut down, a grassland that has been grazed too heavily.*



Post-site Activities

ACTIVITY 16
The fossilization game, part 2

Now that the class is thinking of *ancient organisms in terms of their ecological roles, repeat play of the "fossilization game" (page 11) with paleoecology in mind. Choose animals and plants to make a complete community. When you tally the results, take a look at how complete a representation of the community you have reconstructed. Is it complete or are there parts missing? How* different is *your view of the* reconstructed community *with some parts missing?* Do you think this reconstruction is *unrealistic? What happens when* you play *the game again?*

ACTIVITY 17 Writing about ancient communities

Message — You can use your imagination and what you've learned about communities and fossils to write an interesting story about communities of the past.

Materials — Pencils; writing paper or learning logs.

This activity is similar to activity 12: a picture story on adaptation. Students in this activity are limited to being animals (not plants or animals as in activity 12) because they will write about their favorite foods. The story can be a "formula" based on the descriptions below, or can be free-form.

Procedure

1. Choose the role of an ancient animal. This could be any animal that the students encountered in their visit to a museum or park, or in their reading.

2. **Describe your environment.** This requires some knowledge of the ancient ecosystems as reconstructed by a paleontologist or interpreted by a park ranger or guide. Let the students be as creative as they wish. Some students may include imagined details of the environment that were not previously discussed. This is OK as long as they can justify their reasons.

3. **Describe your community.** In this part, the students should give examples of the other plants and animals that live with them. This information will be available from park rangers or in publications.

4. Describe a food chain. Begin by listing your favorite food. Are you a carnivore or a herbivore? If you are a herbivore, what animal tries to hunt you? How have you kept from getting eaten so far?

5. Describe a food web. Pretend your favorite food disappears. If your favorite food is not available what do you eat? How many different kinds of food fit into your diet? What other kinds of food do the other animals in your food chain (No. 4, above) like to eat?

5. Imagine a big change. What would you do if all your food disappeared because of that change? What could you do? Would you move away? How would the other members of your food web survive? This is an example of an ecological disaster because food chains and food webs would be forced to come apart.

Ancient communities preserved intact

Discovering how extinct plants and animals lived together in their environment is the task of paleoecologists. But there are not many places where it is easy to see all the different parts of ancient ecosystems in one place. Fortunately, one of the best places to see the workings of a complex ancient ecosystem, and even some cases of interaction, is a national monument surrounded by public lands: Fossil Butte National Monument in southwestern Wyoming.

The ancient ecosystem at Fossil Butte centered on three large lakes that existed in the area about 50 million years ago. In those lakes were deposited muds that hardened into the Green River Formation, one of the largest known lake deposits in the world. At certain times during the lakes' history, conditions were favorable for the preservation of fossils. The fossil record of the Green River Formation is an amazing resource for paleontology. Organisms from single-celled bacteria and spores to 16-foot crocodiles are preserved. The fossil flora (plants) is also well represented. Palms and other tropical and subtropical plants tell us that the climate was much warmer than today.

Fish are the most abundant fossils found in the Green River Formation near Fossil Butte; many fish specimens from this area can be seen in museums around the world. The deposit is rich in other vertebrates as well. Frogs, salamanders, lizards, snakes, alligators, birds (including tracks and feathers), bats, and some larger mammals are found among the vertebrate fossils. Invertebrates include clams, snails, prawns, crayfish, and insects.

Most importantly, cases of interaction between different parts of the ancient environment can be seen. A leaf gnawed by an insect, or a fish with another species of fish in its stomach, are examples of direct evidence of ancient food chains. Trackways of birds, lizards, and worms provide striking examples of interactions of animals with their physical environment.

The Fossil Butte visitor center contains a modern museum displaying many plant, vertebrate, and invertebrate fossils collected from the region. Visualizing living things that have been buried in mud, now turned to layer upon layer of rock, will become easier for many children after visiting the Fossil Butte visitor center and looking at nearby exposures of rock.

Fossil Butte National Monument is located 11 miles west of Kemmerer, Wyoming.

A Guide to Fossils, Helmut Mayr, Princeton University Press, 1989. (ISBN 0-691-08789-X) A small picture book packed with information about fossil plants, vertebrates, and invertebrates. A representative selection of the more common fossils, illustrated by exceptionally well-preserved material. The pictures, along with detailed technical descriptions, may be useful in helping amateurs identify fossils.

The Search for the Past, L.B. Halstead, Doubleday & Co., 1982. (ISBN 0-385-18212-0) An encyclopedic, interestingly written and illustrated introduction to geology, sedimentary rocks, and paleontology. Discusses the meaning of fossils, how fossilization occurs, trace fossils, history (including famous hoaxes), and evolution. Enhanced with examples from the around the world. Presents explanations of food webs and other concepts from ecology.

Mighty Mammals of the Past: A Detective Story of Earth's Animal Ancestors, John Stidworthy, Silver Burdette, 1986. (ISBN 0-382-09321-6) A lively account of the rise of mammals. Gives a good introduction to the diversity and ways of life of mammals during the last 60 million years.

Books for children

Evolution, Joanna Cole, Harper Collins Publishers, 1987. (I S B N 0-06-445086-4) Suitable for children in the early elementary grades, this book provides an introduction to some of the ideas of evolution.

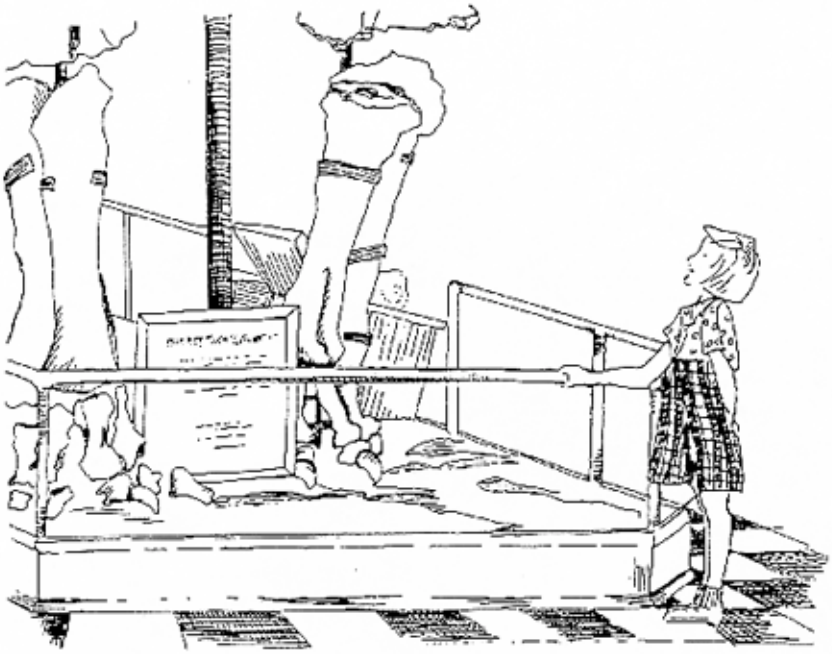
Dinosaurs, a Journey Through Time, Dennis Schatz, Pacific Science Center, 1987. (ISBN 0-935-05101-5) Information on paleontology and ideas about dinosaur life. This book is a good source for classroom or individual activities. Contains cut-outs to make stand-up dinosaurs and game cards.

The Usborne Young Scientist: Evolution, Barbara Cork and Lynn Bresler, EDC Publishing Co., 1986. (ISBN 0-86020-867-2) This book is suited for the upper elementary grades. It contains background material and activities to help the reader understand concepts of evolution.

Video

Dinosaurs, Puzzles From the Past, No. 51046, National Geographic Society, Educational Video Presentations, Washington DC 20036. Excellent 20-minute video about the geological time line.

UNIT FOUR: HUMAN INFLUENCES



Introduction

The National Park System was created by the people of the United States, and its future depends on us as a nation. People who visit the national parks and monuments set examples when they take the time to understand the messages of the parks. Parks are not only places to renew ties with nature and past cultural or historic events, but also exceptional natural classrooms preserved for generations to come. We share the natural, historic, and cultural heritage they preserve. And we share in their care.

Other government agencies such as the Bureau of Land Management also manage, protect, and interpret fossils so that the American people can enjoy and learn from them.

In this unit, students will explore concepts of fossils as nonrenewable scientific resources, and learn how scientists find, manage, and study fossils. Central to this unit is an experience where the students design and staff their own natural history museum. By playing the roles of scientists and professional people they will gain a feeling for some of the routines and frustrations that real paleontologists experience. This experience, along with discussions with a working paleontologist on the staff of a museum, national park, or other government agency, will allow the students to better identify with scientists in general.

Objectives

After studying this unit, students should be able to:

1) explain the scientific importance of fossils in simple terms;

2) express in writing and drawing their understanding of the procedures used in finding, collecting, and preserving fossils; and

3) explain why paleontologists and students should use responsible procedures when studying and collecting fossils.

Materials included in the kit

selection of fossil casts modeling clay

Optional materials

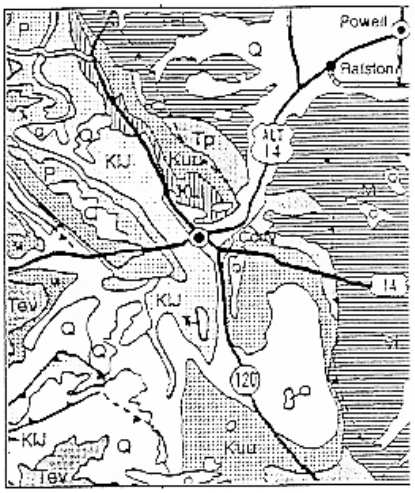
modeling tools paper and crayons

VOCABULARY

Classification	The organizing of living things based on characters that indicate relationship.
Comparative anatomy	The study of similarities and differences in anatomy of different organisms to discover evolutionary relationships.
Curator	An expert on a particular museum collection.
Invertebrate	An animal with no backbone. (See vertebrate.)
Natural resource	A naturally-occurring material that is useful to society.
Paleoenvironment	An ancient environment reconstructed by studying fossils and the rocks in which they were preserved.
Stratigraphy	Study of layered rocks, their distribution, origin, fossil content and relative age. Used to interpret Earth history.
Vertebrate	An animal with a backbone; in general, an animal with bones.

A fossil's journey

• **How do paleontologists find fossils?** The best way to find fossils is to look for them. Paleontologists often spend many days searching the ground for small fragments of fossilized shell or bone that might indicate that something worth digging up lies beneath. Fossils are not found everywhere, so scientists must use clues to help them narrow their search. The best way to start is by studying a geologic map. A geologic map shows the age and type of rocks at the surface (see figure at right). This method works because paleontologists generally know the age of fossils they want to find and whether they lived in a marine (saltwater) or nonmarine (freshwater or dry land) environment. Studying a geologic map will often allow a paleontologist to narrow the search down to a few square miles. Other factors that are important in deciding where to look are how well the rocks are exposed (looking for fossils is more productive where there is less vegetation covering the ground) and who owns the land. Often, permits are required to enter and dig on land owned by state or federal governments. These fossils are owned by the public as a whole. Only certain types of fossils on public land can be collected without a permit. If the land is privately owned, the fossils are the property of the landowner and he or she must give permission.



Geologic map of the area around Cody, Wyoming. \The different patterns show the age and type of rock exposed at the surface.

When a location has been chosen the next step is to begin prospecting. Prospecting is searching the ground for fossils and deciding whether or not anything important lies underneath. Searching for fossils in most areas is very timeconsuming and often frustrating when, after many days of searching, nothing of interest turns up. But there is no better feeling of satisfaction than making a new find.

When a paleontologist finds a fossil he or she must be careful to plot its position on a map so the place can be found again. The fossil or its wrapping is also labeled and notes made so that it can be associated later with its location.

• **Collecting a fossil** In some areas fossils are collected from surface finds only. Elsewhere a surface find may indicate that digging could uncover more fossils. If fossils are small and relatively durable, they may be collected simply by putting them into a box or vial with a little padding. Large fossils, on the other hand, such as those of dinosaurs, may require large-scale excavation and sophisticated wrapping and reinforcement to keep the fragile specimens from breaking up.

Paleontologists usually try to identify what they have found while still in the field. But dirt and rock covering a fossil may make identification difficult, and too much preparation (cleaning) under field conditions may damage the specimen. Thus, careful preparation and study are usually saved for the laboratory. Because of this, exciting discoveries are often made after specimens have been returned to the museum and prepared.

Collecting fossils usually involves collecting more than the fossils themselves. Fossils are useful only if details about where and how they were collected are also recorded. Field paleontologists take careful notes and record everything they find. They record the kind of rock and the position in the "stack" of sedimen-

tary rocks where the fossils were found. The science of stratigraphy deals with the stories told by sequences of rocks-older rocks down low, progressively younger rocks stacked on top. So, knowing the stratigraphic position of a fossil is necessary to add the new fossil information to the stratigraphic story.

Knowing the kind of rock that fossils are preserved in helps put together the story of the environment in which the fossilized plant or animal lived and how it came to be a fossil. When the location of each fossil find and any other information the paleontologist thinks important have been recorded, then it is time to go to the museum.

The first step on returning to the museum is to clean the remaining dirt off the fossil, and glue it together if it is broken so it can be handled and stored. This is called preparation. A preparator is a person trained in the techniques of excavating, cleaning, and strengthening fossils. A preparator also needs to have training in the anatomy of the creatures he or she is preparing, so that important details will not be overlooked or destroyed.

After the fossil is clean and stabilized it can be studied, displayed, or stored for future use. Preparators quite often paint a permanent number on fossils (like a library catalog number on a book) so they can be found later. A collections manager is the person responsible for storing and keeping track of all the fossils in a museum collection.

There are several ways that a fossil can be useful once it is in a museum.. Most fossils are part of research collections. Paleontologists use research collections to study the anatomy of the plants and animals they are interested in, and to discover paleoecological relationships among the different ancient organisms. A museum scientist, called a curator, specializes in the types of plants or animals in a collection. Curators often write books or shorter articles about their research interests. They often use the research collections of many museums to do their work.

Public exhibits constitute another part of a museum's mission. Displays of fossils allow the museum curator's scientific findings to be made available to a wider audience than if they were only described in print. Displays allow fossils and other natural objects to serve an educational purpose for schools and the general public. This is important because museums depend on the general public, either directly, through museum memberships and contributions, or indirectly, through government grants, for the funding that allows them to do their work. Also, paleontologists are justifiably proud of their finds and are eager to share them with as many people as possible.

Conservation of paleontological resources

• **What is a paleontological resource?** Fossils can be thought of as a kind of natural resource, something that occurs in nature that is useful for society. Fossils are non-renewable natural scientific and educational resources. The economic benefit of fossils may be less obvious than that of, say, coal or oil, but they are resources nonetheless. Closely associated with paleontological resources are other important pieces of information. The rocks that fossils are found in are valuable for paleontologists because they can tell about where the fossil organism lived and how it died. Stratigraphy (the story of layers in rock) is also important because it allows scientists to put fossils in perspective. So, the lands around places where fossils are found are needed by

paleontologists to help them understand the resource.

• **How paleontologists conserve paleontological resources** Paleontologists have an unwritten code of ethics that guides them in their work and encourages the most efficient use of the resource. They are careful to get permission from the owner of the land on which they intend to work. If the land is owned by a state or federal government, they must apply for a permit to work there. Application for a permit requires describing what the paleontologist wants to look for and why, what kind of digging will be required, and how long the project will take.

Paleontologists try to disturb the land only as much as necessary to extract the fossils. They also remember to close gates and not disturb livestock that may be present.

Most paleontologists agree that vertebrate fossils, because of their rarity, should be collected and used primarily for scientific research and teaching. Generally, vertebrate fossils are not collected simply to be sold. Because of the quality of molding and casting today, high-quality plastic casts can take the place of actual fossils when it is necessary to share fossils with other museums, schools, or private individuals. Often the sale of casts can pay for part of the expense of excavating and preparing a large fossil.

• **How amateurs can conserve paleontological resources** Amateur paleontologists can and do make valuable scientific discoveries. But their discoveries are valuable to science only if they can be made available to people qualified to study them. For that reason amateurs can be most effective if they work through a museum or university. Scientific contributions can be made if someone recognizes rare and unstudied specimens and brings them to the attention of a specialist.

If done in a professional manner, amateur paleontology can be a successful and rewarding hobby. The greatest rewards **will** come to amateurs who know that their discoveries are going to help the science of paleontology. The true value of a fossil lies in the story it tells about our past. The specialist puts together the stories of many different fossils and adds to the big picture of life in the past. Sharing this knowledge with other scientists, students, and the public can enrich all of our lives.

Pre-questions

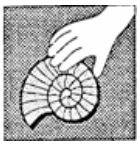
1. When is it good to collect a ***fossil?*** *Children should understand that not even professionals collect fossils unless they are prepared to do so. This includes knowing something about* the *fossils of the area you are collecting in, and knowing how to collect a fossil* without *damaging it. See the discussion in the Overview.*

2. Are there times when it would be best not to collect a ***fossil?*** When? *Fossils should not be collected without permission of the person or government agency that is responsible for the land. If is also best not to collect fossils if you don't yet have experience.*

3. What does a paleontologist do? A *paleontologist studies fossils and puts together stories of life in the past.*

4. Is paleontology important to you? Why or why not?

6. Would you like to be a paleontologist? Why or why not?



Pre-site activities

ACTIVITY 18 A classroom natural history museum

A museum run by the students will provide many opportunities for them to show what they have teamed in paleontology. The large number of different jobs to fill in a museum will also provide a forum for the diverse talents of the students. A classroom museum is a project that could take several weeks or a month to complete, and could be the theme behind the entire unit in paleontology. The classroom museum has some advantages over a public museum in that "hands-on" time is available for students.

The teacher may decide whether the best way to divide the labor of the museum staff is to let the students volunteer for jobs, or to assign them. They will probably work more productively in teams. Whatever the arrangement, it may be a good idea to let them change jobs at least once during the exercise to give each student a feel for more than one job.

Here is a list of possible museum jobs with brief job descriptions. You and the students may think of more.

Jobs in the paleontology museum

Field paleontologist	Collects fossils and records location and stratigraphic information for fossils found.
Preparator	Removes fossils from their field packages, keeping field notes with the fossils. Cleans fossils and prepares them for storage or display.

Photographer	Photographs fossils in the field and in the laboratory for publication and museum records.
Curator	Identifies and studies fossils. Writes scientific articles on fossils, including paleoecology and geology.
Collections manager	Puts fossils in permanent storage and prepares permanent records of all information about each fossil. In charge of maintaining museum records.
Editor	In charge of museum publications.
Writers	Write articles for museum publications and public displays.
Artist (scientific illustrator)	Makes drawings of important fossils for publication and display.
Display designer	Designs and supervises building of displays for public part of the museum.
Guide	Conducts tours through the museum for the public and school groups.
Librarian	Organizes the museum's library. Keeps records of museum publications and other books and journals used for research.

You may decide to limit the scope of the museum and decrease the size of the job list accordingly. For example, if the museum is concerned only with field exploration and research, your museum would employ only field paleontologists, a preparator, curator, photographer, and artist. Much of what the classroom museum decides its mission is depends on the ambitions and talents of the teacher and students.

Build and expand the museum by using casts in this kit and fossils collected by students on field trips. Specimens donated by the students may become a permanent part of the classroom to be used again and augmented in future years. A collection like this will be especially useful if there is no museum or national park unit nearby.

ACTIVITY 19 Paleontology research teams

During the course of studying about fossils, visiting a national park unit or public lands, and putting together their own museum, the students probably have some favorite fossils they would like to know more about. Learning more about these favorite fossils will be the job of the paleontology research teams. Each team consists of three or four students who together find out as much as they can about a particular fossil animal or plant they have encountered. They research its way of life, the environment it lived in, including the other animals and plants, where it lived, and how long ago. The students will probably find that all of the information they would like on their fossil is not available. At this point it will be their job to use what they have teamed about how paleontologists study fossils to make some observations and form their own hypotheses. The team will put together a notebook containing all the information they have gathered.

Some observations the students might make in forming their own paleontological hypotheses:

1. Compare the fossil organism to living plants or animals. Does it look like anything living today?

2. Study the anatomy of the fossil organism. If the fossil is a vertebrate, its teeth will often be the best clue to diet. Are they the teeth of a carnivore or a herbivore?

3. Reconstruct the ancient environment. Use reference books to find out what kinds of plants and animals lived with the fossil organism being studied. How did they live together? Have the students put together the ancient food web.

4. Ask the students to compare their paleoenvironmental reconstruction with the present environment where the fossil was found. Is it similar or different? How much has it changed?

After the data-gathering phase, the teams will be responsible for organizing the information into some form to present their story to the rest of the class. The presentation could be in the form of posters, sculptures, or dioramas. Each team will then present its findings to the rest of the class. Along with visual displays, the students might want to use another medium such as a puppet skit using cardboard cutouts of ancient animals and plants.

A talk with a paleontologist

The best way for students to get a picture of human influences on paleontology is first-hand, from a practicing paleontologist. You might have the opportunity to talk with a paleontologist about his or her job in the course of a visit to a fossil site, or by asking a paleontologist to visit your classroom. The latter case might give you more opportunity to talk about paleontology in general terms.

Many national parks and monuments, and some other land management agencies such as the Bureau of Land Management, will be glad to send a representative trained in paleontology to a school. Museums may also be willing to loan the advice of a person on their staff. Another source might be university geology departments if they have a graduate program in paleontology. There are many people in the community with interest and expertise in paleontology who would be eager to talk to children. Start by calling your local museum, park, BLM office, or state geological survey (see Appendix C, page 74).

Before the visit, tell your paleontologist what the class has been studying and that they are specifically interested in hearing about the science of paleontology itself. Mention that you would like to discuss ethical questions and other problems associated with human influence.

A class exercise before the field trip or visit should be to come up with questions to ask the paleontologist. Students will probably be full of questions now and will have even more to ask when the question session begins. It is a good idea to get some of them on paper beforehand to stimulate discussion and thought. Some possible questions include: Why did you decide to become a paleontologist? What fossils do you like to study most? What is the most exciting fossil you ever found? How do you feel about kids collecting fossils? How do you feel about people collecting fossils to sell? Be sure to allow time for the children's spontaneous questions.

Post-questions

1. Pretend you are a paleontologist. What would you do to make paleontology interesting for people who come to visit your museum? *Answers to this and most of the questions in this set depend on opinions of the students. Some possible answers: make interesting displays; go out and look for new, exciting fossils to study and display.*

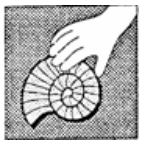
2 **What is something bad that you might do as a paleontologist that would make it hard for other paleontologists to learn about the fossils you find?** *Examples: do a bad job of digging up a fossil; sell a fossil without studying it; put fossils in drawers without good labels so no one can find them.*

3. What kind of fossils did you like learning about most?

4. Is there something about the science of paleontology that would make you want to become a paleontologist? What is it?

5. Do you think that paleontology is a useful thing to do, or would we be better off if paleontologists did something else like fix cars?

7. **What would be the best thing to do if you found a rare fossil while hiking in the hills?** *The best thing to do would be to leave the fossil alone, mark the position on a map or write it down in your notebook, and get the help of someone who is an expert in fossils.*



Post-site activities

ACTIVITY 20 Which bone goes where?

Message **Vertebrate** paleontologists learn how to put fossils together by looking at how bones are arranged in living animals.

Materials Diagrams of skeletons of fossil and living animals (see Appendix E, handout pages 93-94); drawing paper and crayons. Optional: modeling clay and sculpting tools.

Fossils are the raw materials of paleontologists, the source of most information on how extinct plants and animals lived. Vertebrate paleontologists, people who study fossils of animals with skeletons of bones, often have to deal with just a few bones from a skeleton, or haphazard mixtures from different individuals or even different species. It then becomes his or her job to make sense of a confusing situation. How does a vertebrate paleontologist figure out how to put fossil bones together into a skeleton? The answer lies in comparative anatomy.

Comparative anatomy is the science that uses the anatomy of living and fossil organisms to learn about their evolutionary relationships. While comparative

anatomists are often concerned with unique specializations of an animal, that is, features that may indicate some special adaptation, the similarities may also be useful. From the point of view of a vertebrate paleontologist, similarities between extinct and modern animals might be the key to piecing together the skeleton of an extinct beast.

In this exercise the students will compare the skeleton of an extinct vertebrate with that of a living vertebrate. They will then try to stump their classmates by asking them to identify their "mystery bone." Examples will be the drawings of horse and Stegosaurus skeletons found in Appendix E. Other suitable diagrams of animal and human skeletons can be found in veterinary or human anatomy textbooks.

Procedure

1. **Show the drawing of the Stegosaurus skeleton to the class.** Explain to them that fossil skeletons do not always come assembled or complete and that vertebrate paleontologists must put them together from unattached and broken bones. Ask them to come up with some ideas on how a skeleton like this one could be put together.

2. Show the drawing of the horse skeleton. Tell the students that since the horse is a living animal, we know how its bones fit together. Not only that, but we know how the various parts, including the bones, function together.

3. **Compare the two drawings.** Point out a few of the larger and more distinct bones and ask the students to notice the similarities between the two skeletons. The names of some of the major bones are given on the drawings; use this opportunity to introduce a few of these into their vocabularies.

4. **Compare with the human body.** Have the students find each bone on the drawings in their own bodies. Begin at the head (skull and jaws) and work down the neck (neck vertebrae), shoulder (scapula), upper arm bone (humerus), lower arm bones (ulna and radius), ribs, back bones (vertebrae), leg bones (femur, tibia and fibula), and foot bones (metatarsals and phalanges). Tell them that many of the bones in the human body are similar to those in the horse and Stegosaurus.

5. Divide the class into teams. Each team will study one of the drawings and choose a bone as their "mystery bone." They will then collaborate to create a drawing of that bone. Have each team present their mystery bone to the other teams as a contest. The object is to create the most easily-recognized bone in the assigned skeleton. If the other team correctly guesses the mystery bone in one guess, the team gets ten points. If it takes two guesses, they get five points. If it takes three guesses, they get one point. After three turns, the team with the highest score wins.

Variation 1: Paleontological sculptures If sufficient three-dimensional fossils or casts, or very good drawings, are available, the teams could sculpt, rather than draw, their mystery bones.

Variation 2: Specializations Both the horse and Stegosaurus have some bones that are not shared by the other. That is because each is specialized in some way. The horse is adapted for fast running, and therefore its feet have become specialized for running: they are simpler than those of Stegosaurus, with only one toe bone on each foot.

Horses also have very specialized grinding teeth, while the teeth of Stegosaurus are simple pegs.

Stegosaurus, on the other hand, has some very spectacular specializations in its huge armor plates and tail spikes. Some of Stegosaurus's specializations are for defense because it was not a fast runner.

What other differences between the horse and Stegosaurus can you find? Can you think of a possible adaptation for these bones?

Variation 3: Imaginary creatures
Draw a picture of a made-up creature with adaptations for a special way of life. Examples: a fast flier that eats leaves from the tops of trees; a burrowing animal that digs holes so fast no other animal can catch it. Describe how this animal is special and how it accomplishes what it does. Could paleontologists find out about these particular specializations from fossils?

ACTIVITY 21 Ethical questions in paleontology

Message **Paleontologists** have to consider possible harmful effects of their actions. Good ethics pertain to professionals, amateurs, and students.

Materials Sheets of paper or cardboard, drawing instruments.

Paleontologists, like all members of society, have certain responsibilities to the rest of society and the natural environment. These responsibilities are a part of everyday activities. Now that the class has found out first hand how paleontologists do their work, they are ready to think about some ethical consequences of paleontological activities.

Procedure

1. Pick paleontological activities. Begin by dividing the class into groups of three or four. Each group will decide on an activity that a paleontologist might do. Then they will discuss it. Some ideas for activities include, but are not limited to:

    a. hunting for fossils

    b. collecting a fossil for a museum

    c. digging a large excavation

    d. collecting a fossil to sell

    e. taking a picture of a fossil in the field

f. describing the geology of a fossil find in a notebook

g. putting a number on a fossil and putting it in a museum drawer

h. putting together a skeleton in a museum exhibit

The chosen activity might be something the students have seen in their visits to national parks, public lands, or museums.

2. Illustrate each activity. Ask each group to draw a picture of the activity on a card. Make sure they also label the activity. This step is more to make them think about the activity than to be an accurate depiction of it. .

3. **List some positive features of the activity.** Each group will make a short list of positive things about their chosen activity. For example, why is the activity good or necessary? How will it help the person doing the activity? How will it help other people? For example, collecting a fossil to sell might bring in a lot of money that would allow the person selling the fossil to build a big museum.

4. List some negative features. How is the activity detrimental? Will it have negative effects on the person doing the activity or other people? For example, selling a fossil to a private collector would keep it from being studied by scientists. Then no one would ever know that this creature existed. Selling fossils also makes fossils more desirable to collectors who are not scientists. This can make fossils so expensive that museums cannot afford to buy them.

5. Make individual decisions. Would it be possible to make sure that this activity is done only for good, or should responsible people (ethical scientists) refrain from doing it altogether? Allow for disagreement among the students on these points. Some might feel that selling fossils should be outlawed in every case; others might think that some fossils could be sold, but some not at all or only after a scientist has had a chance to study them.

6.Discuss the decisions as a class. After each group has had time for discussion, gather the class back into a single group and discuss the activities together. Lay out the drawings for the class to see. Ask the students to explain their drawings and comment on their own behavior in each circumstance.

National Parks and Monuments And Public Lands

Parks and public lands preserving fossils

In all of the national parks and monuments with significant fossil resources, you will find examples of scientists and teachers using fossils in different ways. In many of these parks you will see how fossils are being studied and interpreted by scientists to team about the past In each national park or monument you will team how the resources of that park are preserved for educational use by scientists, teachers, students, and the public.

A handful of national parks and monuments have been designated "fossil parks" by the National Park Service because of their excellent fossil resources. These are Badlands and Petrified Forest National Parks, and Fossil Butte, Dinosaur, Agate Fossil Beds, Hagerman Fossil Beds, John Day Fossil Beds, and Florissant Fossil Beds National Monuments. These parks have staffs especially eager and able to interpret the paleontoh ogy of the region for visitors.

• Dinosaur National Monument The oldest of these parks, and the only one established primarily to preserve dinosaur fossils, is Dinosaur National Monument, in northeastern Utah and northwestern Colorado. It was designated in 1915 to protect an extraordinary concentration of fossils, dominated by large dinosaurs, discovered by paleontologist Eart Douglass six years earlier. The fossils are preserved in the Momson Formation, deposited in the late Jurassic Period by rivers and lakes. The main fossil-rich bed is a thin sandstone layer, originally a sandbar in one of the ancient rivers, on the south side of Split Mountain in the Utah portion of the monument. The sandstone was tilted to about a 45°-angle by mountain-building forces coinciding with uplift of the Uinta Mountains.

Over the course of fifteen years, tons of fossils were carefully excavated from the dense jumble of bones in the deposit. Many of the dinosaur skeletons went to the Carnegie Museum of Pittsburgh, Pennsylvania, as well as to other museums around the United States. In 1958 the Dinosaur Quarry building was erected over the fossil-rich sandstone to protect the remaining bones and to provide a place where visitors could see them just as they were found. The park staff began to "relief"the bones, removing the sandstone from around them but leaving them in place in the tilted bed. Today, the staff has finished the task of reliefing the bones, and works at various Morrison sites outside the quarry itself. Particularly significant finds (such as an embryo of a small plant-eating dinosaur, and a possible new species of meat-eater) are excavated and brought to the quarry laboratory for preparation, which visitors can watch when it is in progress.

More than 300 partial skeletons of dinosaurs have been found at the Dinosaur Quarry. Many of these are familiar: Allosaurus, Diplodocus, Apafosaurus, Stegosaurus, and Camarasaurus. Fossils of less spectacular but still important crocodiles, turtles, and frogs, as well as freshwater mollusks, are also found in the monument.

Various other National Paris Service areas, though established to preserve other resources, have some dinosaur fossils. The Morrison Formation, with occasional dinosaur bones, is exposed in several other parks and monuments in Utah and Colorado. One of the earliest known dinosaurs was discovered in the Triassic beds of Petrified Forest National Park, Arizona, and some Cretaceous dinosaur fossils occur in Big Bend National Park, Texas.

Many areas of public land have also produced important fossils that are now displayed in museums all over the world. One such site is the Cleveland-Lloyd Dinosaur Quarry in Emery County, Utah. Dozens of dinosaur skeletons were collected from this quarry in the Morrison Formation. Paleontologists are still working at the quarry, and it can be visited by school groups.

In Colorado, the Bureau of Land Management manages the Garden Park Fossil Area near Canon City. A visitor center is planned to showcase the paleontology and history of this area, where dinosaurs have been collected from the Morrison Formation for well over a century. Tours can be arranged by calling the BLM Canon City District Office.

References for further reading

A Field Manual for the Amateur Geologist, Alan Cvancara, Prentice-Hall, 1985. (ISBN 0-13-316530-2) A well-written and invaluable reference for the beginning geologist or paleontologist. Among many useful chapters, one (Ch. 13), titled "Parks for geologic observation and contemplation," contains a summary of noteworthy attractions in 84 national parks, monuments, and seashores. Other highlights are guides for identification of minerals, rocks, and fossils. Appendix A has a list of geological and paleontological museums in the USA and Canada.

Sleuthing Fossils: The Art of Investigating Past Life, Alan Cvancara, Wiley, 1990. (ISBN 0-471-51046-7) A book about fossils for amateurs. It answers some of the pressing questions beginners have about paleontology, such as: How can I collect and properly care for fossils?, and What makes a good paleontologist? Presents fossils as natural resources. Discusses some hot topics in paleontology. Serious amateur paleontologists, some of them even as young as the third grade, will get a lot out of this book.

Handbook of Paleontological Techniques, Bernhard Kummel, W.H. Freeman, 1965. (No ISBN) An old, but still useful, reference for paleontologists in the field and the laboratory. Details techniques of excavation, preparation, and preservation of fossils.

A Field Guide to Dinosaurs, David Lambert, Avon Books, 1983. (ISBN 0-380-83519-3) A beginner's guide to scores of different dinosaurs from around the world with some thought-provoking ideas about the lives and histories of dinosaurs. Contains a list of museum displays featuring dinosaurs.

The Field Guide to Prehistoric Life, David Lambert, Facts on File, 1985. (ISBN 0-8160-1389-6) This book concisely explains concepts of paleontology in layman's terms. Includes plants, invertebrates, and vertebrates. Probably contains more information than a teacher would need for background but might serve as a useful introduction and reference for those deeply interested in the subject.

Geology of Our Western National Parks and Monuments, Royle C. Rowe, Binford and Mort, 1977. (ISBN 0-8323-0237-6) Introduces 52 western national parks through brief summary statements and photographs. Designed to increase geologic knowledge, and therefore, appreciation of national parks and monuments by laypersons. The mostly non-technical discussions will be appreciated by teachers and students.

Pages of *Stone: Geology* of *Western National Parks and Monuments,* Halka Chronic, The Mountaineers, 1984. (ISBNs: Vol. 1, Rocky Mountains and Western Great Plains, 0-89886-095-4; Vol. 2, Sierra Nevada, Cascades, and Pacific Coast, 0-8988x-095-4; Vol. 3, The Desert Southwest, 0-89886-124-1; Vol. 4, Grand Canyon and the Plateau Country, 0-89886-155-1) This well-written four-volume set offers geologic tours through the western national parks and monuments, pointing out highlights and describing in detail the most important features. Each volume begins with an introduction to geologic processes that can be observed in the region discussed. Volume 1 has a fairly extensive non-technical introduction to geology and paleontology that will help even beginners get the most out of a visit. This set would be a useful reference for the classroom.

The Geologic Story of *the National Parks and Monuments,* David V. Harris and Eugene P.1Cnrer, Wiley, 1985. .(ISBN 0-471-87224-5) This book begins with coverage of geologic principles and processes that will be useful for teachers. Discussions of the national parks are organized by "geomorphic provinces," areas with internally similar history and landforms. Treatment is slightly more technical and detailed than the other national park guides, but a layperson should still get a lot out of this guide.

Old Bones and Serpent Stones: A Guide to Interpreted Fossil Localities in Canada and the United States, Volume 2: Western Sites, Theresa Skwara, McDonald and Woodward, 1992. (ISBN: 0-939923-08-4) Handy guidebook describing all areas in the West where one can see fossils interpreted, especially outdoors.

Books for children

Understanding and Collecting Rocks and Fossils, Martin Bramwell, Usbome Publishing Ltd., 1983. (ISBN 0-86020-765-X) This book is best for children in the 4th through 6th grades. It describes what the Earth is made of and explains the forces that are constantly changing it. Looks at rock families, the most common rocks, minerals, and fossils, and explains how to identify and understand them. Also has activities.

Digging up Dinosaurs, Aliki, Crowell, 1981. (ISBN 0-690-04098-9) An interesting introduction to how paleontologists do their work. Describes the roles of people who dig up and prepare fossils (especially dinosaurs) for the museum. Discussions of fossilization, history of paleontology, field work, and mounting skeletons.

Find Out About Dinosaurs, Dougal Dixon, W.H. Smith Publishers, Inc., 1986. (ISBN 0-8317-3326-8) Poses, then answers hundreds of questions not only about dinosaurs, but also about other kinds of fossils and the science of paleontology. Presents some modem concepts and controversies in paleontology in a way understandable to third-graders and older.

Appendices

APPENDIX A:
NATIONAL PARK UNITS WITH FOSSIL RESOURCES

More than sixty national parks and monuments in the United States contain fossils. In some cases these are outstanding fossil resources of major importance. In all cases, they are protected resources that are available for public educational use. The fossils of National Park Service units are valuable resources for expanding the horizons of students of all ages and they should not be overlooked.

National parks and monuments with fossils are found in all parts of the country, although some areas, such as the West, have a higher concentration. The following list is a summary of those parks known to have fossil resources. Some of the facilities that would be useful for instructional use are also given in abbreviated form following the address. This information was obtained by a survey of the parks and was current as of April 1993. The abbreviations are as follows:

SG	facilities well suited for school groups
RC	park representative available to talk to a class
PS	paleontologist on park staff
RP	research being done on paleontological resources in park
MD	museum displays of fossils
PL	fossil preparation laboratory
TC	teaching or research collection (not on display)
HO	hands-on fossil exhibit
NW	interpretive nature walk
FW	interpretive walk emphasizing fossils
IP	fossils visible in place in outcrop
PC	publications available that could be useful in classroom
NF	facilities not especially suited for paleontology
'	fossils **rare**

ALASKA

Aniakchak National Monument & Preserve
PO Box 7
King Salmon AK 99613
Bering Land Bridge National Preserve
PO Box 220
Nome AK 99762 (RC RP TC IP)

Cape Krusenstern National Monument
PO Box 1029
Kotzebue AK 99752

Katmai National Park and Preserve
PO Box 7
King Salmon AK 99613 (SG RC RP TC NW FW IP)

Kobuk Valley National Park
PO Box 1029
Kotzebue AK 99752

Noatak National Preserve
PO Box 1029
Kotzebue AK 99752

Wrangell - St Elias National Park and Preserve
PO Box 29
Glenallen AK 99588 (IP)

Yukon - Charley Rivers National Preserve
PO Box 167
Eagle AK 99738-0167 (SG RC RP MD TC I P)

ARIZONA

Glen Canyon National Recreation Area
PO Box 1507
Page AZ 86040

Grand Canyon National Park
PO Box 129
Grand Canyon AZ 86023 (MD RC NW FP IP)

Petrified Forest National Park
PO Box 217
Petrified Forest National Park AZ 86028-0217
(SG RC RP MD TC HO NW FW IP PC)

Walnut Canyon National Monument
Walnut Canyon Road
Flagstaff AZ 86004-9705 (SG NW)

Wupatki National Monument
HC 33
Box 444 A
Flagstaff AZ 86004

ARKANSAS
Buffalo National River
PO Box 1173
Harrison AR 72601 (SG MD TC NW IP)
CALIFORNIA
Channel Islands National Park
1901 Spinaker Drive
Ventura CA 93001
(SG RC MD TC HO NW FW IP PC)

Death Valley National Monument
Death Valley CA 92328

Point Reyes National Seashore
Point Reyes CA 94956 (SG MD HO IP)
Redwood National Park
1111 Second Street
Crescent City CA 95531

Santa Monica Mountains National Recreation Area
22900 Ventura Boulevard
Suite 140
Woodland Hills CA 91364

Sequoia National Park
Three Rivers CA 93271

COLORADO
Bent's Old Fort National Historic Site
35110 Highway 194 East
La Junta CO 81050-9523 (NF)

Black Canyon of the Gunnison National Monument-
PO Box 1648
Montrose CO 81402 (SG RC NW)

Colorado National Monument
Fruita CO 81521-9530 (SG MD TC NW PC)
Dinosaur National Monument
Dinosaur Quarry .
PO Box 128
Jensen UT 84035 (SG RC PS RP MD PL.IP PC)
Florissant Fossil Beds National Monument
PO Box 185
Florissant CO 80816
(SG PC PS RP MD TC HC NW FW IP PC)
Mesa Verde National Park
Mesa Verde National Park CO 81330

GUAM
War in the Pacific National Historical Park
PO Box FA
Agana GU 96910
HAWAII
Haleakala National Park
PO Box 369
Makawao HI 96768-0369 (SG RC MD NW)

IDAHO

Hagerman Fossil Beds National Monument
963 Blue Lakes Boulevard
Suite 1
Twin Falls ID 83301
KENTUCKY

Mammoth Cave National Park
Mammoth Cave KY 42259

MONTANA

Bighorn Canyon National Recreation Area
PO Box 458
Ft Smith MT 59035

Glacier National Park
West Glacier MT 59936
NEBRASKA

Agate Fossil Beds National Monument
PO Box 427
Gering NE 69341
(SG RC RP MD HO NW FW IP PC)

Scotts Bluff National Monument
PO Box 427
Gering NE 69341
NEVADA

Great Basin National Park
Baker NV 89311 (SG PR MD NW IP)
Lake Mead National Recreation Area
601 Nevada Highway
Boulder City NV 89005-2426

NEW JERSEY
Delaware Water Gap National Recreation Area
Bushkill PA 18324 (SG MD TC HO NW FW IP PC)
NEW MEXICO

Carlsbad Caverns National Park
PO Box 1598
Carlsbad NM 88220

Chaco Culture National Historical Park
Star Route 4 Box 6500
Bloomfield NM 87413 (SG RC HO IP)

Salinas National Monument
PO Box 496
Mountainair NM 87036

NORTH DAKOTA

Theodore Roosevelt National Park
PO Box 7
Medora ND 58645 (RC MD NW FW IP)

OREGON

Crater Lake National Park
PO Box 7
Crater Lake OR 79604 (MD NW PC ')
John Day Fossil Beds National Monument
420 West Main Street
John Day OR 97845
(RC PS RP MD PL TC HO NW FW IP PC)

PENNSYLVANIA

Delaware Water Gap National Recreation Area
Bushkill PA 18324 (SG MD TC HO NW FW IP PC)

Valley Forge National Historical Park
PO Box 953
Valley Forge PA 19481-0953 (NF)

SOUTH DAKOTA

Badlands National Park
PO Box 6
Interior SD 57750 (RC MD TC HO NW FW IP PC)

Wind Cave National Park
Hot Springs SD 57747

TEXAS
Big Bend National Park
Big Bend National Park TX 79834
Guadalupe Mountains National Park
HC 60 Box 400
Salt Flat TX 79847-9400
(SG RC RP MD PL TC HO NW FW IP PC)

Padre Island National Seashore
9405 S Padre Island Drive
Corpus Christi TX 78418-5597

UTAH

Arches National Park
PO Box 907
Moab UT 84532 (SG RC MD NW)

Bryce Canyon National Park
Bryce Canyon UT 84717
(SG RC RP MD TC HO NW)

Canyonlands National Park
125 West 200 South
Moab UT 84532

Capitol Reef National Park
Torrey UT 84775
Cedar Breaks National Monument
PO Box 749
Cedar City UT 84720 (SG RC MD NW)

Dinosaur National Monument
Dinosaur Quarry
PO Box 128
Jensen UT 84035 (SG RC PS RP MD PL IP PC)

Natural Bridges National Monument
PO Box 1
Lake Powell UT 84533 (SG RC MD NW ')

Timpanogos Cave National Monument
RR 3 Box 22
American Fork UT 84003
(SG RC PS RP MD NW FW IP)

Zion National Park
Springdale UT 84767-1099

VIRGINIA

Colonial National Historical Park
PO Box 210
Yorktown VA 23690

George Washington Birthplace National Monument
RR 1 Box 717
Washington's Birthplace VA 22443 (SG RC HO)

Petersburg National Battlefield
PO Box 549
Petersburg VA 23804-0949(NF)

WASHINGTON

Olympic National Park
600 East Park Avenue
Port Angeles WA 98362

WEST VIRGINIA

New River Gorge National River
PO Box 1189
Oak Hill WV 25901

WYOMING

Devils Tower National Monument
Devils Tower WY 82714 (SG MD NW)

Fossil Butte National Monument
PO Box 592
Kemmerer WY 83101
(SG RC PS RP MD PL TC HO NW FW PC)

Grand Teton National Park
PO Drawer 170
Moose WY 83012 (MD NW)

Yellowstone National Park
PO Box 168
Yellowstone National Park WY 82190
(SG RC IP RP NW FW)

APPENDIX B:
BUREAU OF LAND MANAGEMENT
STATE OFFICES AND INTERPRETED PALEONTOLOGICAL SITES

STATE OFFICES

Alaska
Anchorage Federal Office Building
222 West 7th Avenue #13
Anchorage AK 99513-7599
(907)271-5960

Arizona
3707 North 7th Street
PO Box 16563
Phoenix AZ 85011
(602)650-0200

California
Federal Building
2800 Cottage Way Room E 2841
Sacramento CA 95825-1889
(916)978-4746

Colorado
2850 Youngfield Street
Lakewood CO 80215
(303)239-3600

Idaho
3380 Americana Terrace
Boise ID 83706
(208)384-3000

Montana - North Dakota - South Dakota
Granite Tower
222 North 32nd Street
PO Box 36800
Billings MT 59107
(406)255-2885

Nevada
Federal Building Room 3123
850 Harvard Way
PO Box 12000
Reno NV 89520-0006
(702)785-6500

New Mexico - Oklahoma - Texas - Kansas
1474 Rodeo Road
PO Box 27115
Santa Fe NM 87502-0115
(505)438-7400

Oregon - Washington
1300 NE 44th Avenue
PO Box 2965
Portland OR 97208-2965
(503)280-7001

Utah
324 South State Street Suite 301
PO Box 45155
Salt Lake City UT 84145-0155
(801)539-4001

Wyoming - Nebraska
2515 Warren Avenue
PO Box 1828
Cheyenne WY 82003-1828
(307)775-6256

All other states
Eastern States Office
7450 Boston Boulevard
Springfield VA 22153-3121
(703)440-1600

INTERPRETED PALEONTOLOGICAL SITES
ON **PUBLIC LANDS**

Note: Collecting *vertebrate* fossils on lands administered by the BLM requires a permit issued by the appropriate BLM State Office. Visitors may collect reasonable quantities of common *invertebrate* fossils and petrified wood for their personal use (fossils may not be sold, bartered, or traded) on public lands unless otherwise posted. No *fossil collecting is* allowed in the special areas listed below, so that all visitors may enjoy seeing the fossils.

COLORADO

• Dinosaur Hill I Riggs Hill • Stewart Valley Paleontological Area
• Rabbit Valley Trail Through Time Mineral County Museum, Hawthorne, has exhibits of
These sites in the Grand Junction-Fruita area feature Miocene land mammals, plants, and fish from this
interpretive trails through the Jurassic dinosaurbone- area. Interpretive signs are posted on gravel roads
bearing Morrison Formation. Contact BLM District through Stewart Valley. Contact BLM Carson City
Office or Museum of Western Colorado (both in Grand District Office for more information.
Junction) for more information.

NEVADA

OREGON

• Garden Park Fossil Area • Fossil Lake
Historic and modern dinosaur quarries in the Jurassic Interpretive signs are posted at the two major
Morrison Formation near Canon City. Garden Park entrances to this area near Christmas Valley, which
Paleontological Society and Denver Museum of was covered by a Pleistocene fresh-water lake that
Natural History do research and provide tours and attracted millions of birds and other animals. Contact
information. Contact BLM District Office, Canon City, BLM Lakeview Resource Area Office for more
for more information. information.
• Picketwire Tracksite UTAH
Hundreds, of dinosaur tracks in the Jurassic Morrison • **Cleveland-Lloyd Dinosaur Quarry**
Formation near the Purgatoire River can be visited This site in the Jurassic Morrison Formation south of
during dry weather. Tours are given on Saturdays and Price has produced thousands of bones of Allosaurus.
by appointment. Contact BLM District Office, Canon It features an interpretive center, outbuildings housing
City, for more information. exhibits of dinosaur bones in the ground, and a self
guided trail. Contact BLM District Office or CEU
• Kremmling Cretaceous Ammonite Locality Prehistoric Museum (both in Price) for more
Fossil ammonites (nautilus-like shellfish) in the Pierre information.
Shale, difficult to access. Contact BLM Kremmling
Resource Area Office for more information or to • Moab Dinosaur Tracks
schedule a visit. Several kinds of carnivorous dinosaurs left their tracks
in the early Jurassic Kayenta Formation near Moab.

IDAHO Auto tours pamphlet available at the Moab Visitor
• Sand Point Fossil Area Center describes the area; BLM Moab District Office
Pliocene sediments of the Idaho Group near Hammett has information and a fossil display.
contain fossil snails and document the development of
a huge lake that once covered much of southwest • Mill Canyon Dinosaur Trail
Idaho. Contact BLM in Boise for more information. Self-guiding trail leads visitors to exposed and
preserved dinosaur bones in the Jurassic Morrison
• Maim Gulch Formation north of Moab. Interpretive brochure
Several horizons in the Eocene Challis Volcanics available from BLM Moab District Office.
contain fossil stumps, trunks, leaves, and fruits of
hardwoods, pines, and dawn redwoods. Contact the
BLM Salmon District Office before visiting the site.

APPENDIX C:
STATE GEOLOGICAL SURVEYS

Geological Survey of Alabama
PO Box O
Tuscaloosa AL 35486-9780
(205)349-2852

Alaska Division of Geological and Geophysical Surveys
3700 Airport Way
Fairbanks AK 99709
(907)451-8760

Arizona Geological Survey
845 North Park Avenue
Tucson AZ 85719
(602)621-7906

Afnsas Geological Commission
Vardelle Parham Geology Center
3815 West Roosevelt Road
Little Rock AR 72204
(501)371-1488 or 663-9714

Resources Agency
Department of Conservation
Division of Mines and Geology
1416 Ninth Street Room 1341
Sacramento CA 95814
(916)445-1923

Colorado Geological Survey
Department of Natural Resources
715 State Centennial
1313 Sherman Street
Denver CO 80203
(303)866-2611

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State Geological and Natural History Survey
Natural Resources Center
Department of Environmental Protection
165 Capitol Avenue
Hartford CT 06106
(203)566-3540

Delaware Geological Survey
University of Delaware
Newark DE 19716
(302)451-2833

Florida Geological Survey
BU(elffU of Geology
Florida Department of Natural Resources
903 West Tennessee Street
Tallahassee FL 32304-7795
((04)488-4191

Georgia Geologic Survey
Branch of Environmental Protection Division
Georgia Department of Natural Resources
Room 400
19 Martin Luther King Jr Drive SW
Atlanta GA 30334
(404)656-3214

Division of Land Development
Department of Land and Natural Resources
PO Box 373
Honolulu HI 96809
(808)548-7533

Idaho Geological Survey
University of Idaho
Moscow ID 83843
(208)885-7991

Illinois State Geological Survey
Department of Energy and Natural Resources
Natural Resources Building
615 East Peabody Drive
Champaign IL 61820
(217)333-4747

Indiana Geological Survey
Division, Indiana Department of Natural Resources
611 North Walnut Grove
Bloomington IN 47405
(812)335-9350

Geological Survey Bureau
Iowa Department of Natural Resources
123 North Capitol Street

Iowa City IA 52242
(319)335-1575

Kansas Geological Survey
The University of Kansas
1930 Constant Avenue
West Campus
Lawrence KS 66046-2598
(913)864-3965

Kentucky Geological Survey
University of Kentucky
228 Mining and Mineral Resources Building
Lexington KY 40506-0107
(606)257-5500

Louisiana Geological Survey
Department of Natural Resources
PO Box G
University Station
Baton Rouge LA 70893
(504)388-5320

Maine Geological Survey
Maine Department of Conservation
State House Station 22
Augusta ME 04333
(207)289-2801

Maryland Geological Survey
Department of Natural Resources
2300 St Paul Street
Baltimore MD 21218
(301)554-5500

Executive Office of Environmental Affairs
100 Cambridge Street
20th Floor
Boston MA 02202
(617)727-9800

Michigan Geological Survey
Department of Natural Resources
PO Box 30028
735 E Hazel Street
Lansing MI 48909

Minnesota Geological Survey
School of Earth Sciences
University of Minnesota
2642 University Avenue
St Paul MN 55114-1057
(612)627-4780

Bureau of Geology
Mississippi Department of Natural Resources
PO Box 5348
Jackson MS 39218
(601)354-6228

Division of Geology and Land Survey
Missouri Department of Natural Resources
111 Fairgrounds Road
Buehler Park
Rolla MO 65401
(314)364-1752

Montana Bureau of Mines and Geology
Montana College of Mineral Science and Technology
West Park Street
Butte MT 59701
(406)496-4181

Conservation and Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
113 Nebraska Hall
Lincoln NE 68588-0517
(402)472-3471

Nevada Bureau of Mines and Geology
University of Nevada-Reno
Reno NV 89557-0088
(702)784-6691

Office of the State Geologist
University of New Hampshire
117 James Hall
Durham NH 03824
(603)862-3160

New Jersey Geological Survey Element
Water Resources Division
Department of Environmental Protection
Box CN-029
Trenton NJ 08625
(609)292-1185

New Mexico Bureau of Mines and Mineral Resources
Division of New Mexico Institute of Mining and Technology
Campus Station
Socorro NM 87801
(505)835-5420

New York State Geological Survey
New York State Museum
State Education Department
Cultural Education Center
Albany NY 12230
(518)474-5816

Geological Survey Section
Division of Land Resources
North Carolina Department of Natural Resources and Community Development
PO Box 27687
Raleigh NC 27611
(919)733-3833

North Dakota Geological Survey
University Station
Grand Forks ND 58202-8156
(701)777-2231

Division of Geological Survey
Ohio Department of Natural Resources
Fountain Square
Building B
Columbus OH 43224
(614)265-6605

Oklahoma Geological Survey
University of Oklahoma
Board of Regents
830 Van Vleet Oval
Room 163
Norman OK 73019
(405)325-3031

Oregon Department of Geology and Mineral Industries
910 State Office Building
1400 SW Fifth Avenue
Portland OR 97201
(503)229-5580

Bureau of Topographic and Geological Survey
Department of Environmental Resources
PO Box 2357
Harrisburg PA 17120
(717)787-2169

Office of the State Geologist
Department of Geology
The University of Rhode Island
Kingston RI 02881
(401)792-2265/2184

South Carolina Geological Survey
South Carolina State Budget and Control Board
Division of Research and Statistical Services
5 Geology Road
Columbia SC 29210
(803)737-9440

South Dakota Geological Survey
Department of Water and Natural Resources
Science Center
University of South Dakota
Vermillion SD 57069
(605)677-5227

Tennessee Division of Geology
Department of Conservation
701 Broadway
Customs House
Nashville TN 37219-5237
(615)742-6691

Texas Bureau of Economic Geology
The University of Texas at Austin
University Station
Box X
Austin TX 78713
(512)471-1534 or471-7721

Utah Geological and Mineral Survey
Utah Department of Natural Resources
606 Black Hawk Way
Salt Lake City UT 84108-1280
(801)581-6831

Office of the State Geologist
Agency of Natural Resources
103 South Main Street
Center Building
Waterbury VT 05676
(802)244-5164

Division of Mineral Resources
Department of Mines, Minerals and Energy
Natural Resources Building
PO Box 3667
Charlottesville VA 22903

Division of Geology and Earth Resources
Department of Natural Resources
Olympia WA 98504
(206)459-6372

West Virginia Geological and Economic Survey
Mont Chateau Research Center
PO Box 879
Morgantown WV 26507-0879
(304)594-2331

Wisconsin Geological and Natural History Survey
University of Wisconsin-Extension
3817 Mineral Point Road
Madison WI 53705
(608)262-1705

The Geological Survey of Wyoming
Box 3008
University Station
Laramie WY 82071-3008
(307)721-3920 or 766-2286

APPENDIX D: GEOLOGICAL TIME SCALE

Approximate millions of years before present	ERA	PERIOD	EPOCH	Approximate duration (millions of years)	ANIMAL LIFE	PLANT LIFE
0.01	CENOZOIC	Quaternary	Recent (Holocene)	0.01	Modern humans.	Woody plants less common.
			Pleistocene	1.6	Ice Age. Evolution of humans. Rise and extinction of giant mammals. Horses become extinct in North America.	Extinction of many species.
1.6		Tertiary	Pliocene	3.7	Early human relatives.	Modern plants. Fewer forests.
5.3			Miocene	18.7	First true deer.	Grasslands spread.
24			Oligocene	13	First rhinoceroses.	Monocots common.
37			Eocene	21	First relatives of camels, horses, whales, elephants, cats, and dogs.	First grasses.
58			Paleocene	7	Many modern orders of mammals appear.	First monocots; dicots common.
65	MESOZOIC	Cretaceous		79	Appearance of first primates, snakes, and modern birds. Most groups of mammals still primitive. Extinction of dinosaurs, pterosaurs, large marine reptiles, and ammonites and many other invertebrates at end of Cretaceous.	Angiosperms spread. Gymnosperms decline.
144		Jurassic		64	Dinosaurs dominant. First birds, frogs, salamanders, and pterosaurs (flying reptiles).	First sequoias. Cycads and conifers common; angiosperms (plants with covered seeds) appear.
208		Triassic		37	First dinosaurs, ichthyosaurs (fish-like marine reptiles), turtles, crocodiles, and mammals. Reptiles start to dominate life on dry land. Giant amphibians become extinct.	Primitive seed ferns become extinct. Gymnosperms dominant.
245	PALEOZOIC	Permian		41	Abundant types of reptiles. First mammal-like reptiles. Major extinction event involving many invertebrates at end of Permian.	Lycopods, horsetails, seed ferns, and gymnosperms become less common.
286		Carboniferous * Pennsylvanian Mississippian		74	Amphibians dominate dry land. First reptiles and flying insects (some very large).	First forests. Coal swamps with horsetails and lycopods (primitive plants). First conifers and ginkgos (gymnosperms).
360		Devonian		48	The "Age of Fishes." Large fishes in seas. First ammonites (nautilus-like cephalopods) and sharks. First land vertebrates (amphibians).	First seed plants (gymnosperms, with naked seeds).
408		Silurian		30	First jawed fishes. Armored (jawless) fishes become abundant.	First known land plants.
439		Ordovician		67	First vertebrates (jawless fishes). Abundant invertebrates in seas.	Simple mosses and lichens may have lived on land.
505		Cambrian		65	Animals become abundant in the fossil record. All major groups (phyla) of animals present. First snails, clams, corals, and cephalopods (relatives of squid).	Great numbers of marine algae appear in the fossil record.
570	PRECAMBRIAN	Begins with origin of Earth 4.6 billion years ago.		4000	Mostly soft-bodied, worm-like animals that leave few traces in the fossil record. Primitive arthropods and mollusks.	Primitive plant-like bacteria (blue-green algae). Some build stromatolites (layered, dome-shaped mounds).

*Carboniferous is standard worldwide; in the U.S. the Mississippian and Pennsylvanian periods are often used instead.

The story of how a rabbit became a fossil

1. The living rabbit. Where an animal lives is important in determining its chances of becoming a fossil after it dies. An animal that lives next to the water like this rabbit will have a much better chance of fossilization than one that lives far from water.

2. The rabbit dies.

3. The dead rabbit (carcass) is swept into the water by a flood. It lies on the bottom and begins to decay.

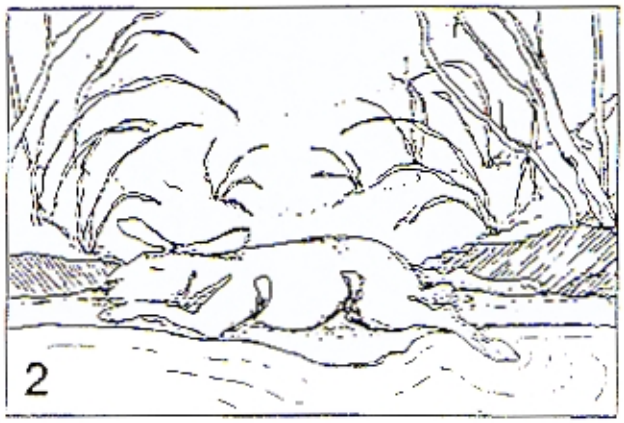
4. The soft parts decay away. Normally, bones and flesh become a source of food for scavengers. For an animal to become a fossil, something must happen so scavengers are excluded. This could happen if :there is not enough oxygen in the water to breathe or if the dead animal is buried quickly.

5. The skeleton is buried in sediment.

6. The sediments build up to great thickness. They are squeezed together by the weight of the sediments on top of them. After a long time they turn to sedimentary rock.

7. The sedimentary rocks are uplifted and slightly tilted by geological forces. Erosion cuts through the stack of rocks, exposing the fossil.


1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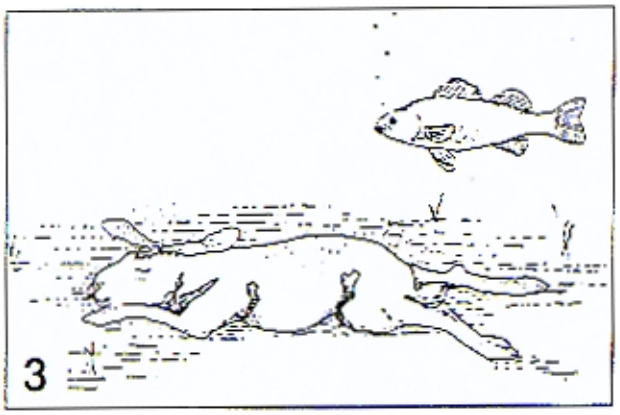
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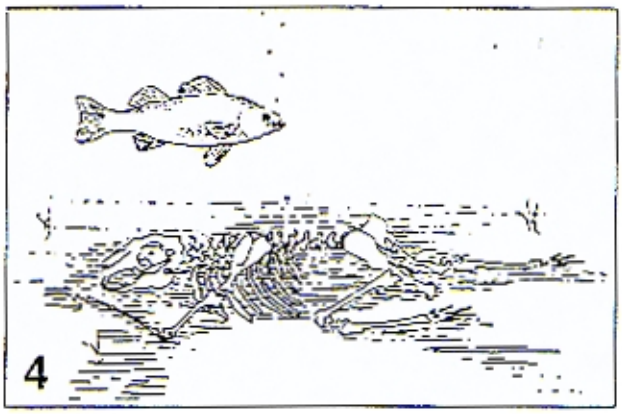
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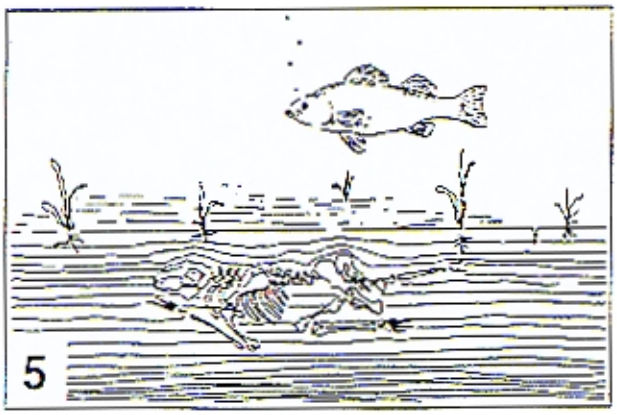
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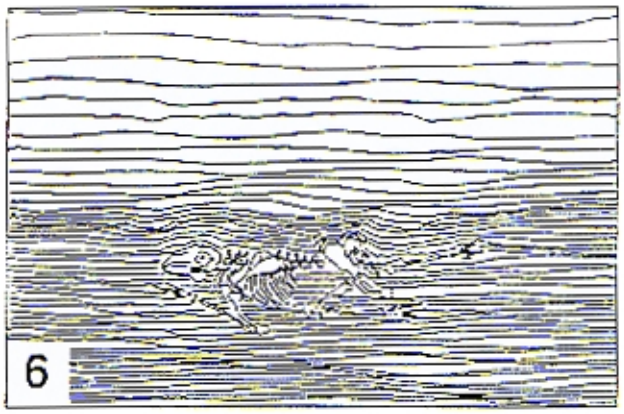
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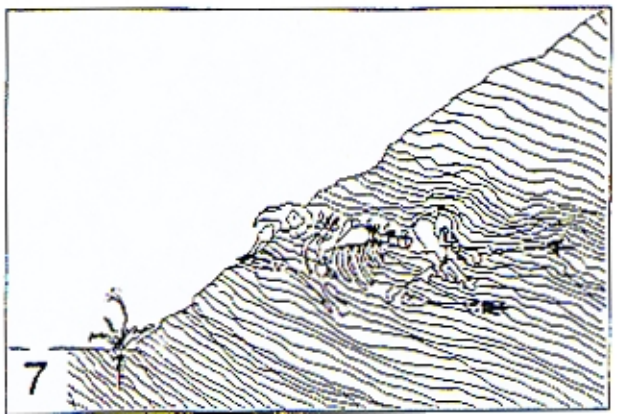
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UNIT ONE: FOSSILIZATION

Pre-Questions

1. What is a fossil?

2. How does an animal or plant become a fossil?

3. Your footprints on the beach are evidence that you were there. Do you think you could call your footprints trace fossils? Why or why not? If they were still there after 20,000 years, could you call them fossils then?

UNIT ONE: FOSSILIZATION

Post-questions

1. What are some ways that an animal or plant could become a fossil? (Name as many different ways as you can think of?

2. What three things are required for a living thing to become a fossil?

3. Why is it normally so hard for a plant or animal to become a fossil after it dies?

4. What is the difference between a "normal" fossil (body fossil) and a trace fossil?

4. Why are fossils important? What do they tell us?

5. The hard parts of a living thing may be preserved for millions of years in rock. This is:very important evidence that cannot be replaced, like the evidence a detective finds at the scene of a crime. It tells us how living things were different in the past. What can you do to protect this evidence?

7. Name some national parks or monuments or sites on public lands that have fossils. What kind of fossils are they?

UNIT TWO: ADAPTATION

Pre-Questions

1. What is an environment?

2. What is your environment like?

3. What kinds of animals and plants live with you in your environment?

4. What is a fossil?

5. What can we learn from studying fossils?

UNIT TWO: ADAPTATION

Post-Questions

1. What are the two parts of an environment?

2. How are fossils important to us?

3. What kind of animals and plants lived in the past at the national park, monument, or area that you visited? What do these fossils tell us about the environment at that time? Has the environment changed? How is it different?

4. How are the fossil animals and plants of the place you visited different from the ones living today in that same area?

5. Could you find places where the environment today is similar to the ancient environment at your field trip site? Where?

6. How do we know what ancient animals were like?

7. What happens to an animal or plant when the environment changes?

8. What are some ways that animals or plants can become extinct?

9. List some animals that are extinct. How many of these have gone extinct recently?

10. What are some things that humans do to the environment that might be bad for living things (including us)?

UNIT THREE: COMMUNITY

Pre-questions

1. Where does your food come from?

2. How can a paleontologist learn about the community of plants and animals living at times in the past?

UNIT THREE: COMMUNITY

Post-questions

1. Think about the fossils of the place you visited on your field trip that lived together. Which ones are predators? Which are the prey? Are there some that you cannot tell?

2. Make a food chain for the fossil animals and plants you are studying.

3. With the help of your classmates, construct a food web for the animals and plants that lived at the time of the fossils you studied on the field trip.

4. How does a predator species depend on its prey?

5. How does a prey species depend on predators?

5. Where does your food come from? (Hint: think of the food chain. Vegetables and grains you eat come directly from green plants that get their food from sunlight. Meat you eat comes from animals that eat green plants?

6. How healthy would an ecosystem be if many of its parts are missing? For example, what if there are very few predators?

8. Can you think of an example of an unhealthy ecosystem?

UNIT FOUR: HUMAN INFLUENCES

Pre-questions

1. When is it good to collect a fossil?

2. Are there times when it would be best not to collect a fossil? When?

3. What does a paleontologist do?

4. Is paleontology important to you? Why or why not?

5. Would you like to be a paleontologist? Why or why not?

UNIT FOUR: HUMAN INFLUENCES

Post-questions

1. Pretend you are a paleontologist. What would you do to make paleontology interesting for people who come to visit your museum?

2. What is something bad that you might do as a paleontologist that would make it hard for other paleontologists to learn about the fossils you find?

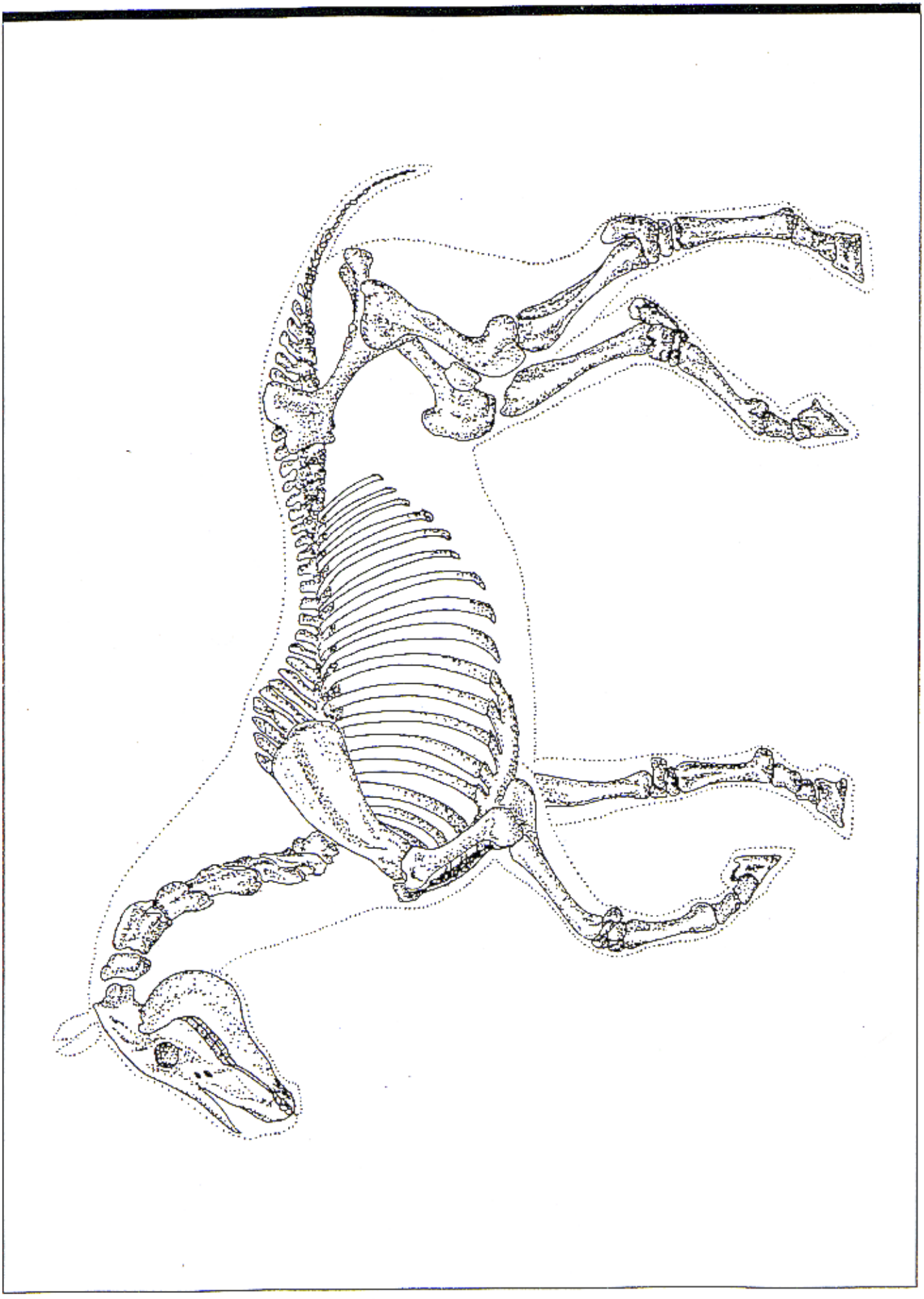
3. What kind of fossils did you like learning about most?

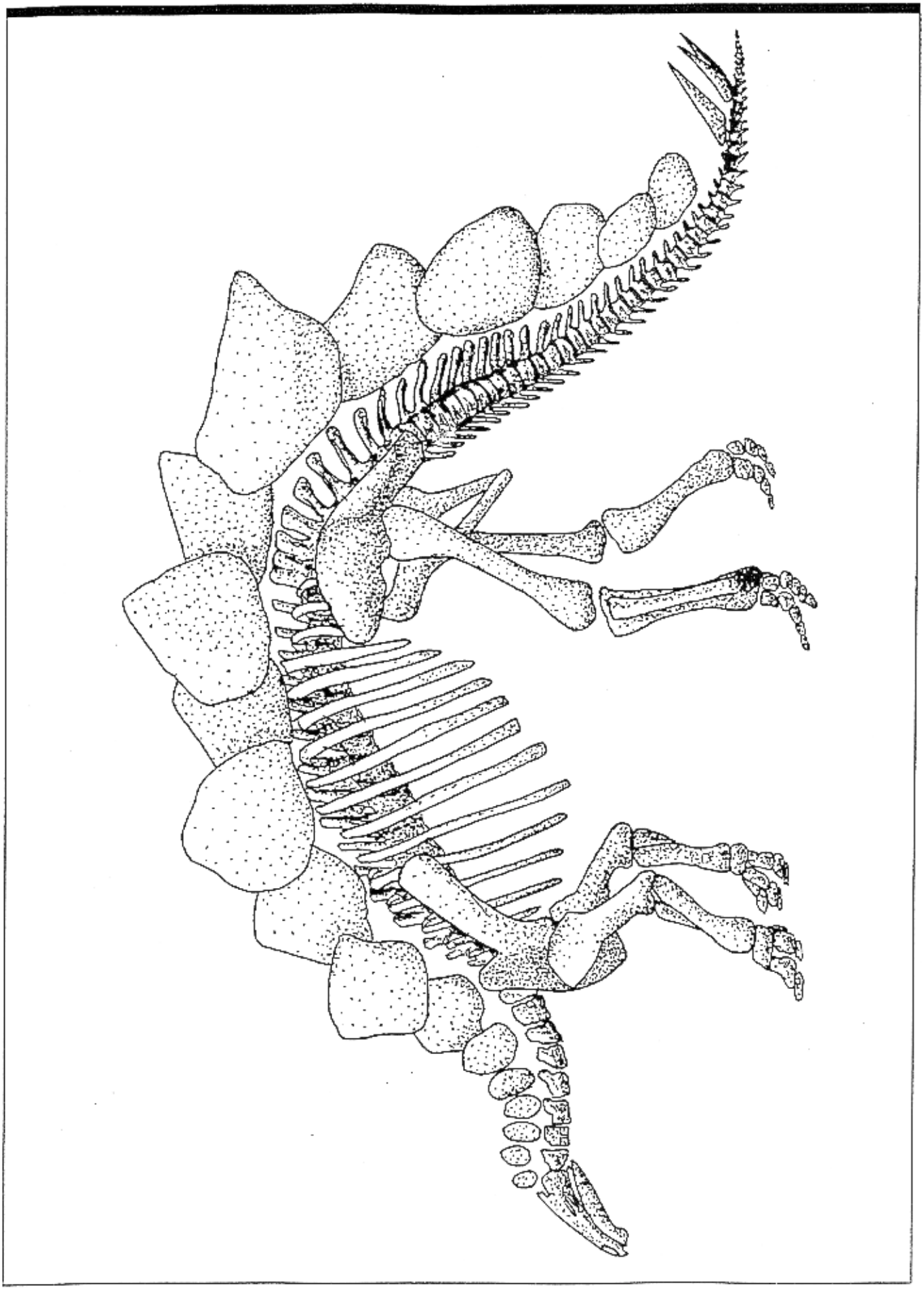
4. Is there something about the science of paleontology that would make you want to become a paleontologist? What is it?

5. Do you think that paleontology is a useful thing to do, or would we be better off if paleontologists did something else like fix cars?

6. What would be the best thing to do if you found a rare fossil while hiking in the hills?

DRY UP	DRY UP
ROT AWAY	ROT AWAY
ROT AWAY	SWALLOWED BY ALLIGATOR
SWALLOWED BY CROCODILE	SWALLOWED BY CROCODILE
SWALLOWED BY BIG FISH	SWALLOWED BY BIG FISH
EATEN BY SCAVENGERS	EATEN BY SCAVENGERS
BURIED IN SOFT MUD— YOU BECOME A FOSSIL!	BURIED IN MUDSLIDE— YOU BECOME A FOSSIL!
WASHED AWAY BY WAVES	WASHED AWAY BY WAVES
WASHED AWAY BY CURRENT	WASHED AWAY BY CURRENT





Stratigraphy

The stratigraphic section on the next page is an actual section from the Green River Formation on public lands near Fossil Butte National Monument in Wyoming. It shows 11 meters of sedimentary rock and the fossils that were collected from them. The different patterns are symbols for different kinds of rocks (see key below). The legend at the bottom of the section explains the symbols for fossils. These symbols are drawn next to the level at which they were found. In several cases, more than one kind of fossil is found in the same layer.

Plotting the stratigraphic position (level) of fossils makes it easy to judge the relative age of different sets of fossils. By plotting fossils and rock types together, paleontologists can see if certain fossils frequently occur in the same type of rock. By comparing stratigraphic sections from different areas, scientists can study regional conditions and how they changed through time. This is how the story of life in the past is put together.

This stratigraphic section could be used as an exercise in addition and subtraction (it is a kind of rJmber line). The questions on the handout are intended to help children understand why paleontologists are interested in the stratigraphic position of fossils they collect. Remember, rocks and fossils that formed first (the oldest) are at the *bottom* of the section; younger rocks and fossils lie above.

Answers to questions on the handout page

1. The youngest fish is the one nearest the top of the diagram. It is located about 8 meters from the bottom. Other fossils found with this fish are coprolites and plant parts.

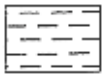
2. The oldest clam (the one nearest the bottom) was found a little over 2 meters from the bottom of the section. The youngest clam was found 11 meters from the bottom. The difference (11-2) is 9 meters.

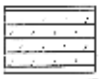
3. Coprolites were found at eight different levels.

4. Coprolites were found with leaves, clams, fish, plant parts, and insects. A good guess about where the coprolites came from would be fish. Insects, clams, or shrimp could be other answers. The students could also guess a number of different animals (especially if they are familiar with the fossils of Fossil Butte National Monument), but there is no evidence from this particular section that any other animal was there.

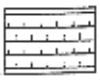
Key to rock symbols


Very thin limestone layers

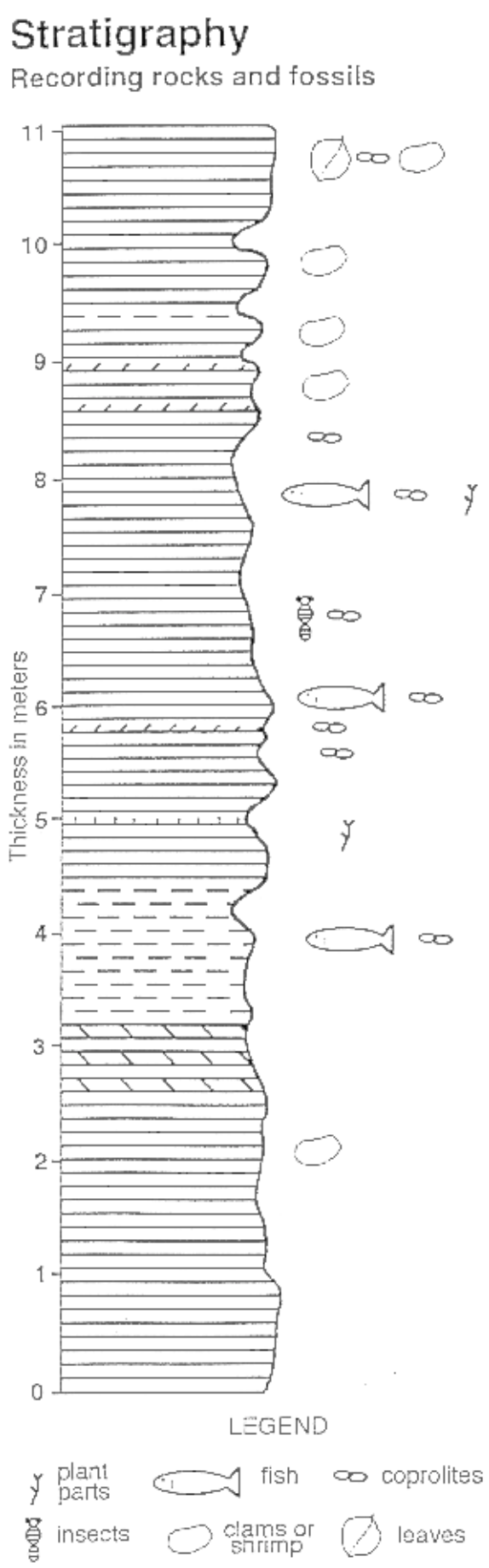

Thin, silica-rich rocks with no carbonate minerals


Dolomitic siliceous rocks


Calcareous siliceous rocks


Aragonitic rocks

Section redrawn from Buchheim, *H. P., Paleolimnology of the Laney Member of the Eocene Green River Formation,* Ph.D. Dissertation, University of Wyoming, 1978.



Questions

1. How many meters high in the section is the youngest fish? What other kinds of fossils were found with this fish?

2. How many meters above the oldest clam was the youngest clam found?

3. At how many different levels were coprolites found?

4.With what other kinds of fossils were coprolites found? What animals would you guess these coprolites could be from?

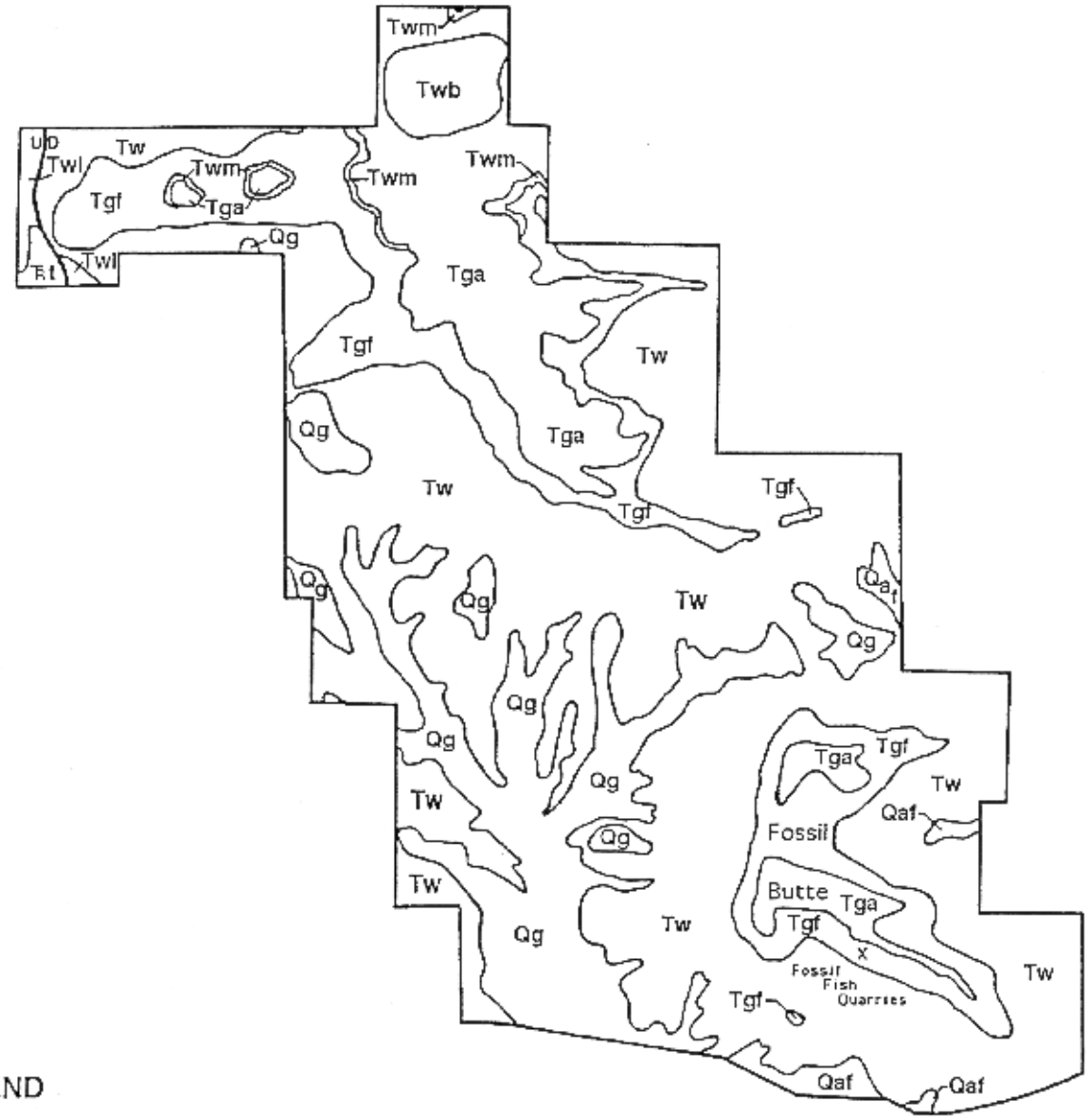
Geologic Map

On the following page is a geologic map of the area around Fossil Butte National Monument in Wyoming. Geologic maps show the formations (rock layers) and *members (parts* of formations) that are exposed at the surface. Each formation or member is given a different color or pattern on the map to make it stand out from the others.

The map in this handout has not been colored, but each of the formations is labeled with an abbreviated name. These abbreviations are explained in the legend below the map. The rock names in the legend are arranged stratigraphicafiy, that is, with the oldest rocks on the bottom and progressively younger rocks as you go up. Rocks represented on this map are from the Triassic Period, the Eocene Epoch of the Tertiary Period, and the Quaternary Period.

The object of this exercise is to color each of the rock layers on the map a different color. Use similar colors for the members of each formation. For example, you might color the four members of the Wasatch Formation red, pink, reddish-orange, and orange. When you are done, you will have a real geologic map.

Geologic Map of Fossil Butte National Monument



LEGEND

Age	Symbol	Color	Name of formation or member
Quaternary	Qg - Qaf		Gravel and stream deposits
Eocene	Tga		Angelo member of Green River Formation
	Tgf		Fossil Butte member of Green River Formation
	Twb		Bullpen member of Wasatch Formation
	Twm		Mudstone member of Wasatch Formation
	Tw		Main body of Wasatch Formation
	Twl		Lower member of Wasatch Formation
Triassic	Rt		Thaynes Limestone (only in northwestern corner)

PALEONTOLOGY MUSEUM

Specimen card

Specimen number _____

Name of fossil _____

_____

Locality _____

Identified by _____

Collector _____

Date collected _____

PALEONTOLOGY MUSEUM

Specimen card

Specimen number _____

Name of fossil _____

_____

Locality _____

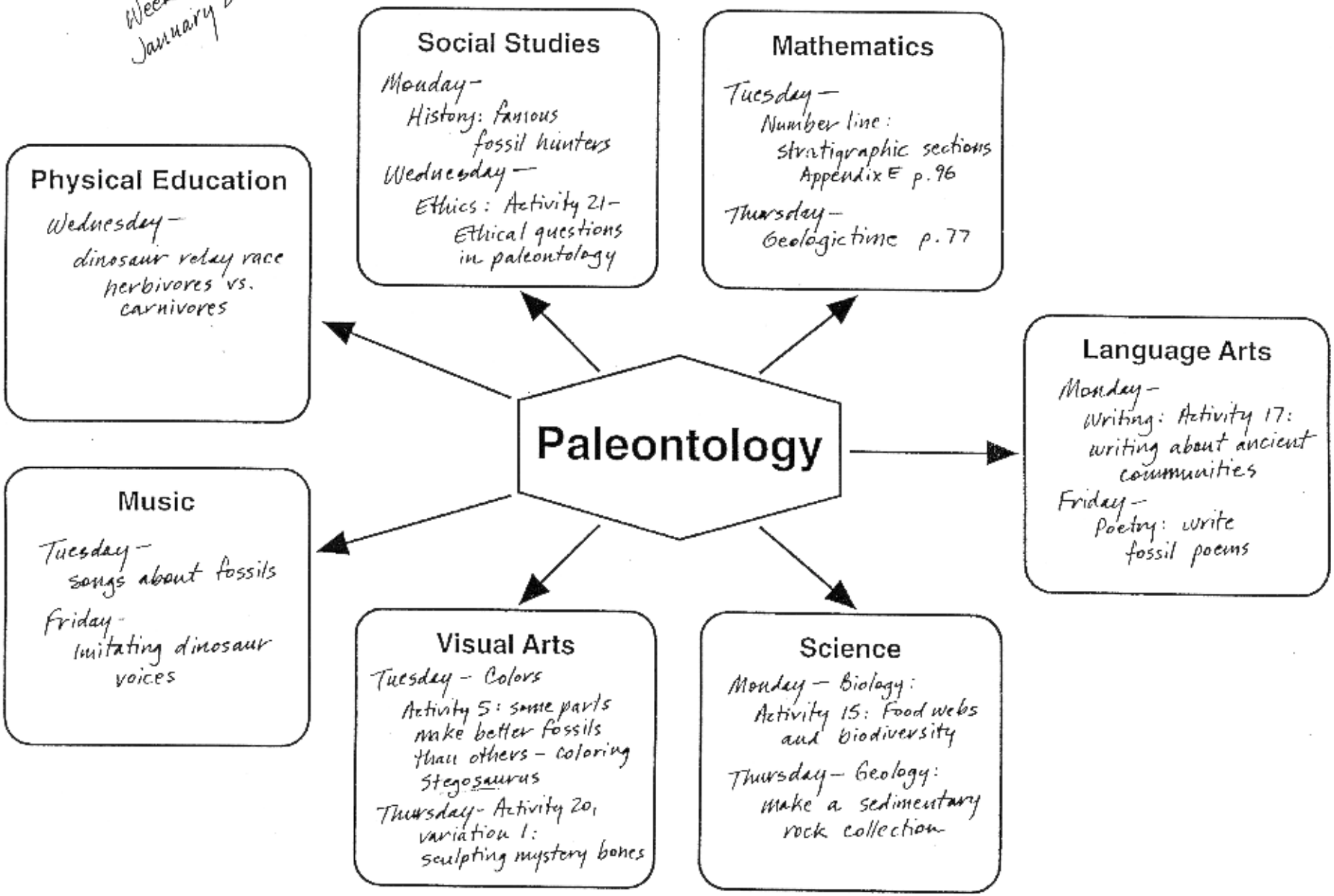
Identified by _____

Collector _____

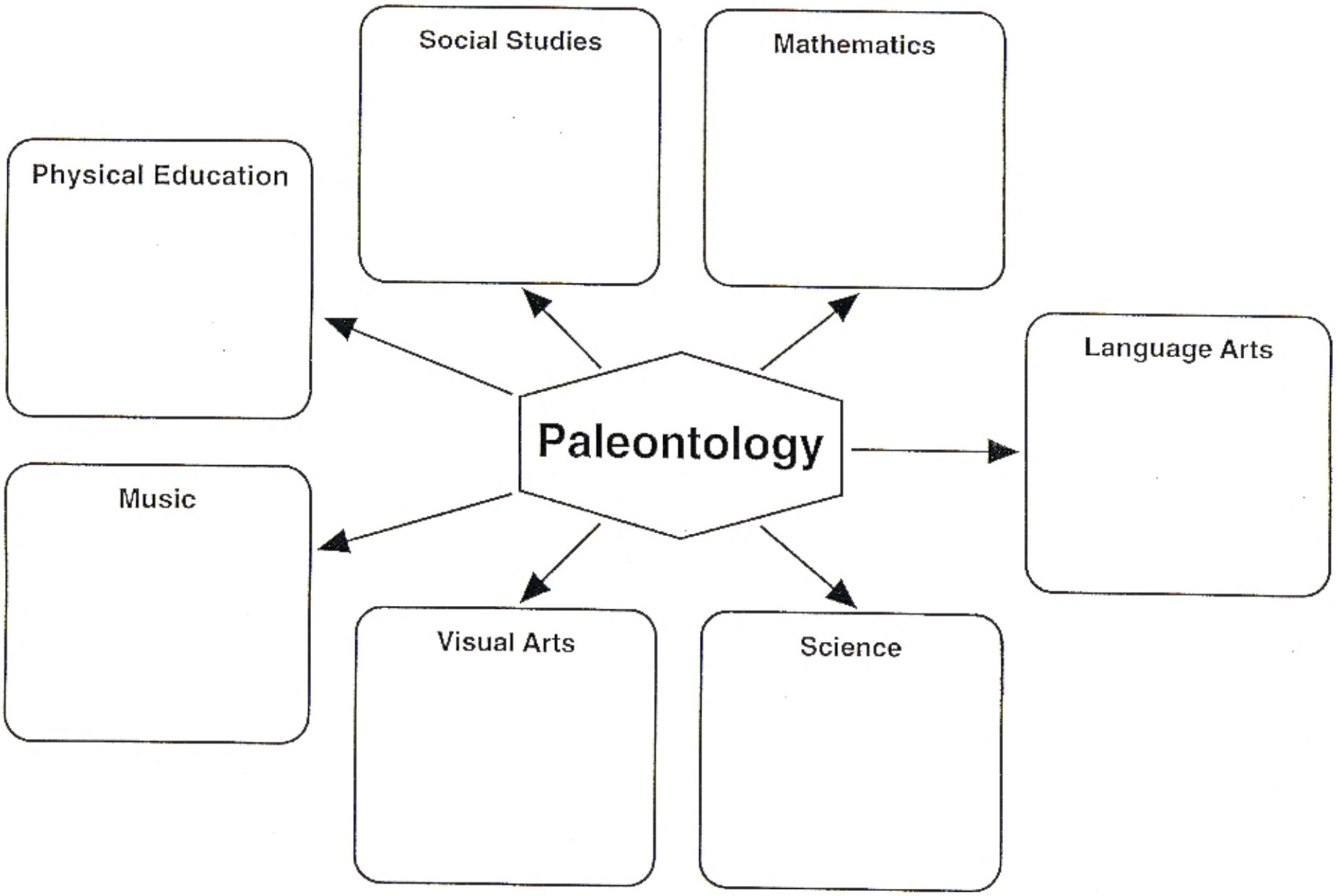
Date collected _____

Classroom Planning Chart (sample)

Week of January 21st



Classroom Planning Chart



APPENDIX F:
SOURCES FOR CLASSROOM FOSSIL CASTS

Dino Productions
P.O. Box 3004
Englewood, CO 80155

Dinosaur Nature Association
1291 E. Highway 40
Vernal, UT 84078

Geo Science Industries
4015 S. Taft Hill Rd.
Fort Collins, CO 80526

Geoscience Resources
2990 Anthony Rd.
Burlington, NC 27215

Jones Fossil Farm
East Acres Park
Worthington, MN 56187

Saurus
530 S. 4th East
Centerville, UT 84104

Ward's Natural Science Establishment, Inc.
5100 West Henrietta Rd.
P.O. Box 92912
Rochester, NY 14692-9012

GROWING SECTION

The following pages contain ideas on classroom paleontology that were contributed by previous users of the teaching guide. This section will grow as the guide is used. We hope these ideas are useful in your teaching of paleontology.

If you have some ideas generated by your classroom experiences, we would be glad to include them in the guide. Fossil Butte National Monument is the collecting point for teacher contributions. Send your ideas to:

Fossil Butte National Monument
Environmental Education Program
PO Box 592
Kemmerer WY 83101-0592

Teacher Evaluation Form

Your comments on this form will help us improve future editions of the teaching guide. You may use additional pages for any other comments or suggestions. Please return the completed form with the kit. Thank you.

Teacher's name _____

School _____ Grade level _____

Which units did you use?

☐ Unit 1 ☐ Unit 2 ☐ Unit 3 ☐ Unit 4

Did the Overview sections cover the material clearly?

Were the questions appropriate for the students' level and the material covered?

Which of the exercises did you find most helpful in teaching? Which were least helpful?

Was the computer simulation (Unit 3) useful in your classroom?

Which version did you use?

☐ IBM ☐ Apple

Did you or the students experience any problems with the software? Explain.

What materials did you use from the kit?

What, if any, other materials should be included in the kit?

Comment on the quality and appropriateness of the fossil casts.

Additional comments (use other sheets if necessary):